PostgreSQL 9.4.1 Documentation

The PostgreSQL Global Development Group

PostgreSQL 9.4.1 Documentation

by The PostgreSQL Global Development Group

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Preface

This book is the official documentation of PostgreSQL. It has been written by the PostgreSQL developers and other volunteers in parallel to the development of the PostgreSQL software. It describes all the functionality that the current version of PostgreSQL officially supports.

To make the large amount of information about PostgreSQL manageable, this book has been organized in several parts. Each part is targeted at a different class of users, or at users in different stages of their PostgreSQL experience:

- Part I is an informal introduction for new users.
- Part II documents the SQL query language environment, including data types and functions, as well as user-level performance tuning. Every PostgreSQL user should read this.
- Part III describes the installation and administration of the server. Everyone who runs a PostgreSQL server, be it for private use or for others, should read this part.
- Part IV describes the programming interfaces for PostgreSQL client programs.
- Part V contains information for advanced users about the extensibility capabilities of the server. Topics include user-defined data types and functions.
- Part VI contains reference information about SQL commands, client and server programs. This part supports the other parts with structured information sorted by command or program.
- Part VII contains assorted information that might be of use to PostgreSQL developers.

1. What is PostgreSQL?

PostgreSQL is an object-relational database management system (ORDBMS) based on POSTGRES, Version 4.2[1], developed at the University of California at Berkeley Computer Science Department. POSTGRES pioneered many concepts that only became available in some commercial database systems much later.

PostgreSQL is an open-source descendant of this original Berkeley code. It supports a large part of the SQL standard and offers many modern features:

- complex queries
- foreign keys
- triggers
- updatable views
- transactional integrity
- multiversion concurrency control

Also, PostgreSQL can be extended by the user in many ways, for example by adding new

- data types
- functions
- operators
- aggregate functions
- index methods

1. http://db.cs.berkeley.edu/postgres.html

- procedural languages

And because of the liberal license, PostgreSQL can be used, modified, and distributed by anyone free of charge for any purpose, be it private, commercial, or academic.

2. A Brief History of PostgreSQL

The object-relational database management system now known as PostgreSQL is derived from the POSTGRES package written at the University of California at Berkeley. With over two decades of development behind it, PostgreSQL is now the most advanced open-source database available anywhere.

2.1. The Berkeley POSTGRES Project

The POSTGRES project, led by Professor Michael Stonebraker, was sponsored by the Defense Advanced Research Projects Agency (DARPA), the Army Research Office (ARO), the National Science Foundation (NSF), and ESL, Inc. The implementation of POSTGRES began in 1986. The initial concepts for the system were presented in *The design of POSTGRES* , and the definition of the initial data model appeared in *The POSTGRES data model* . The design of the rule system at that time was described in *The design of the POSTGRES rules system*. The rationale and architecture of the storage manager were detailed in *The design of the POSTGRES storage system* .

POSTGRES has undergone several major releases since then. The first “demoware” system became operational in 1987 and was shown at the 1988 ACM-SIGMOD Conference. Version 1, described in *The implementation of POSTGRES* , was released to a few external users in June 1989. In response to a critique of the first rule system (*A commentary on the POSTGRES rules system*), the rule system was redesigned (*On Rules, Procedures, Caching and Views in Database Systems*), and Version 2 was released in June 1990 with the new rule system. Version 3 appeared in 1991 and added support for multiple storage managers, an improved query executor, and a rewritten rule system. For the most part, subsequent releases until Postgres95 (see below) focused on portability and reliability.

POSTGRES has been used to implement many different research and production applications. These include: a financial data analysis system, a jet engine performance monitoring package, an asteroid tracking database, a medical information database, and several geographic information systems. POSTGRES has also been used as an educational tool at several universities. Finally, Illustra Information Technologies (later merged into Informix[2], which is now owned by IBM[3]) picked up the code and commercialized it. In late 1992, POSTGRES became the primary data manager for the Sequoia 2000 scientific computing project[4].

The size of the external user community nearly doubled during 1993. It became increasingly obvious that maintenance of the prototype code and support was taking up large amounts of time that should have been devoted to database research. In an effort to reduce this support burden, the Berkeley POSTGRES project officially ended with Version 4.2.

2. http://www.informix.com/
3. http://www.ibm.com/
4. http://meteora.ucsd.edu/s2k/s2k_home.html

2.2. Postgres95

In 1994, Andrew Yu and Jolly Chen added an SQL language interpreter to POSTGRES. Under a new name, Postgres95 was subsequently released to the web to find its own way in the world as an open-source descendant of the original POSTGRES Berkeley code.

Postgres95 code was completely ANSI C and trimmed in size by 25%. Many internal changes improved performance and maintainability. Postgres95 release 1.0.x ran about 30-50% faster on the Wisconsin Benchmark compared to POSTGRES, Version 4.2. Apart from bug fixes, the following were the major enhancements:

- The query language PostQUEL was replaced with SQL (implemented in the server). (Interface library libpq was named after PostQUEL.) Subqueries were not supported until PostgreSQL (see below), but they could be imitated in Postgres95 with user-defined SQL functions. Aggregate functions were re-implemented. Support for the `GROUP BY` query clause was also added.
- A new program (psql) was provided for interactive SQL queries, which used GNU Readline. This largely superseded the old monitor program.
- A new front-end library, `libpgtcl`, supported Tcl-based clients. A sample shell, `pgtclsh`, provided new Tcl commands to interface Tcl programs with the Postgres95 server.
- The large-object interface was overhauled. The inversion large objects were the only mechanism for storing large objects. (The inversion file system was removed.)
- The instance-level rule system was removed. Rules were still available as rewrite rules.
- A short tutorial introducing regular SQL features as well as those of Postgres95 was distributed with the source code
- GNU make (instead of BSD make) was used for the build. Also, Postgres95 could be compiled with an unpatched GCC (data alignment of doubles was fixed).

2.3. PostgreSQL

By 1996, it became clear that the name "Postgres95" would not stand the test of time. We chose a new name, PostgreSQL, to reflect the relationship between the original POSTGRES and the more recent versions with SQL capability. At the same time, we set the version numbering to start at 6.0, putting the numbers back into the sequence originally begun by the Berkeley POSTGRES project.

Many people continue to refer to PostgreSQL as "Postgres" (now rarely in all capital letters) because of tradition or because it is easier to pronounce. This usage is widely accepted as a nickname or alias.

The emphasis during development of Postgres95 was on identifying and understanding existing problems in the server code. With PostgreSQL, the emphasis has shifted to augmenting features and capabilities, although work continues in all areas.

Details about what has happened in PostgreSQL since then can be found in Appendix E.

3. Conventions

The following conventions are used in the synopsis of a command: brackets (`[` and `]`) indicate optional parts. (In the synopsis of a Tcl command, question marks (`?`) are used instead, as is usual in Tcl.)

Braces ({ and }) and vertical lines (|) indicate that you must choose one alternative. Dots (. . .) mean that the preceding element can be repeated.

Where it enhances the clarity, SQL commands are preceded by the prompt =>, and shell commands are preceded by the prompt $. Normally, prompts are not shown, though.

An *administrator* is generally a person who is in charge of installing and running the server. A *user* could be anyone who is using, or wants to use, any part of the PostgreSQL system. These terms should not be interpreted too narrowly; this book does not have fixed presumptions about system administration procedures.

4. Further Information

Besides the documentation, that is, this book, there are other resources about PostgreSQL:

Wiki

The PostgreSQL wiki[5] contains the project's FAQ[6] (Frequently Asked Questions) list, TODO[7] list, and detailed information about many more topics.

Web Site

The PostgreSQL web site[8] carries details on the latest release and other information to make your work or play with PostgreSQL more productive.

Mailing Lists

The mailing lists are a good place to have your questions answered, to share experiences with other users, and to contact the developers. Consult the PostgreSQL web site for details.

Yourself!

PostgreSQL is an open-source project. As such, it depends on the user community for ongoing support. As you begin to use PostgreSQL, you will rely on others for help, either through the documentation or through the mailing lists. Consider contributing your knowledge back. Read the mailing lists and answer questions. If you learn something which is not in the documentation, write it up and contribute it. If you add features to the code, contribute them.

5. Bug Reporting Guidelines

When you find a bug in PostgreSQL we want to hear about it. Your bug reports play an important part in making PostgreSQL more reliable because even the utmost care cannot guarantee that every part of PostgreSQL will work on every platform under every circumstance.

The following suggestions are intended to assist you in forming bug reports that can be handled in an effective fashion. No one is required to follow them but doing so tends to be to everyone's advantage.

We cannot promise to fix every bug right away. If the bug is obvious, critical, or affects a lot of users, chances are good that someone will look into it. It could also happen that we tell you to update to a newer version to see if the bug happens there. Or we might decide that the bug cannot be fixed before

5. http://wiki.postgresql.org
6. http://wiki.postgresql.org/wiki/Frequently_Asked_Questions
7. http://wiki.postgresql.org/wiki/Todo
8. http://www.postgresql.org

some major rewrite we might be planning is done. Or perhaps it is simply too hard and there are more important things on the agenda. If you need help immediately, consider obtaining a commercial support contract.

5.1. Identifying Bugs

Before you report a bug, please read and re-read the documentation to verify that you can really do whatever it is you are trying. If it is not clear from the documentation whether you can do something or not, please report that too; it is a bug in the documentation. If it turns out that a program does something different from what the documentation says, that is a bug. That might include, but is not limited to, the following circumstances:

- A program terminates with a fatal signal or an operating system error message that would point to a problem in the program. (A counterexample might be a "disk full" message, since you have to fix that yourself.)
- A program produces the wrong output for any given input.
- A program refuses to accept valid input (as defined in the documentation).
- A program accepts invalid input without a notice or error message. But keep in mind that your idea of invalid input might be our idea of an extension or compatibility with traditional practice.
- PostgreSQL fails to compile, build, or install according to the instructions on supported platforms.

Here "program" refers to any executable, not only the backend process.

Being slow or resource-hogging is not necessarily a bug. Read the documentation or ask on one of the mailing lists for help in tuning your applications. Failing to comply to the SQL standard is not necessarily a bug either, unless compliance for the specific feature is explicitly claimed.

Before you continue, check on the TODO list and in the FAQ to see if your bug is already known. If you cannot decode the information on the TODO list, report your problem. The least we can do is make the TODO list clearer.

5.2. What to Report

The most important thing to remember about bug reporting is to state all the facts and only facts. Do not speculate what you think went wrong, what "it seemed to do", or which part of the program has a fault. If you are not familiar with the implementation you would probably guess wrong and not help us a bit. And even if you are, educated explanations are a great supplement to but no substitute for facts. If we are going to fix the bug we still have to see it happen for ourselves first. Reporting the bare facts is relatively straightforward (you can probably copy and paste them from the screen) but all too often important details are left out because someone thought it does not matter or the report would be understood anyway.

The following items should be contained in every bug report:

- The exact sequence of steps *from program start-up* necessary to reproduce the problem. This should be self-contained; it is not enough to send in a bare `SELECT` statement without the preceding `CREATE TABLE` and `INSERT` statements, if the output should depend on the data in the tables. We do not have the time to reverse-engineer your database schema, and if we are supposed to make up our own data we would probably miss the problem.

The best format for a test case for SQL-related problems is a file that can be run through the psql frontend that shows the problem. (Be sure to not have anything in your `~/.psqlrc` start-up file.) An easy way to create this file is to use pg_dump to dump out the table declarations and data needed to set the scene, then add the problem query. You are encouraged to minimize the size of your example, but this is not absolutely necessary. If the bug is reproducible, we will find it either way.

If your application uses some other client interface, such as PHP, then please try to isolate the offending queries. We will probably not set up a web server to reproduce your problem. In any case remember to provide the exact input files; do not guess that the problem happens for "large files" or "midsize databases", etc. since this information is too inexact to be of use.

- The output you got. Please do not say that it "didn't work" or "crashed". If there is an error message, show it, even if you do not understand it. If the program terminates with an operating system error, say which. If nothing at all happens, say so. Even if the result of your test case is a program crash or otherwise obvious it might not happen on our platform. The easiest thing is to copy the output from the terminal, if possible.

  Note: If you are reporting an error message, please obtain the most verbose form of the message. In psql, say `\set VERBOSITY verbose` beforehand. If you are extracting the message from the server log, set the run-time parameter log_error_verbosity to `verbose` so that all details are logged.

  Note: In case of fatal errors, the error message reported by the client might not contain all the information available. Please also look at the log output of the database server. If you do not keep your server's log output, this would be a good time to start doing so.

- The output you expected is very important to state. If you just write "This command gives me that output." or "This is not what I expected.", we might run it ourselves, scan the output, and think it looks OK and is exactly what we expected. We should not have to spend the time to decode the exact semantics behind your commands. Especially refrain from merely saying that "This is not what SQL says/Oracle does." Digging out the correct behavior from SQL is not a fun undertaking, nor do we all know how all the other relational databases out there behave. (If your problem is a program crash, you can obviously omit this item.)
- Any command line options and other start-up options, including any relevant environment variables or configuration files that you changed from the default. Again, please provide exact information. If you are using a prepackaged distribution that starts the database server at boot time, you should try to find out how that is done.
- Anything you did at all differently from the installation instructions.
- The PostgreSQL version. You can run the command `SELECT version();` to find out the version of the server you are connected to. Most executable programs also support a `--version` option; at least `postgres --version` and `psql --version` should work. If the function or the options do not exist then your version is more than old enough to warrant an upgrade. If you run a prepackaged version, such as RPMs, say so, including any subversion the package might have. If you are talking about a Git snapshot, mention that, including the commit hash.

  If your version is older than 9.4.1 we will almost certainly tell you to upgrade. There are many bug fixes and improvements in each new release, so it is quite possible that a bug you have encountered

in an older release of PostgreSQL has already been fixed. We can only provide limited support for sites using older releases of PostgreSQL; if you require more than we can provide, consider acquiring a commercial support contract.

- Platform information. This includes the kernel name and version, C library, processor, memory information, and so on. In most cases it is sufficient to report the vendor and version, but do not assume everyone knows what exactly "Debian" contains or that everyone runs on i386s. If you have installation problems then information about the toolchain on your machine (compiler, make, and so on) is also necessary.

Do not be afraid if your bug report becomes rather lengthy. That is a fact of life. It is better to report everything the first time than us having to squeeze the facts out of you. On the other hand, if your input files are huge, it is fair to ask first whether somebody is interested in looking into it. Here is an article[9] that outlines some more tips on reporting bugs.

Do not spend all your time to figure out which changes in the input make the problem go away. This will probably not help solving it. If it turns out that the bug cannot be fixed right away, you will still have time to find and share your work-around. Also, once again, do not waste your time guessing why the bug exists. We will find that out soon enough.

When writing a bug report, please avoid confusing terminology. The software package in total is called "PostgreSQL", sometimes "Postgres" for short. If you are specifically talking about the backend process, mention that, do not just say "PostgreSQL crashes". A crash of a single backend process is quite different from crash of the parent "postgres" process; please don't say "the server crashed" when you mean a single backend process went down, nor vice versa. Also, client programs such as the interactive frontend "psql" are completely separate from the backend. Please try to be specific about whether the problem is on the client or server side.

5.3. Where to Report Bugs

In general, send bug reports to the bug report mailing list at <pgsql-bugs@postgresql.org>. You are requested to use a descriptive subject for your email message, perhaps parts of the error message.

Another method is to fill in the bug report web-form available at the project's web site[10]. Entering a bug report this way causes it to be mailed to the <pgsql-bugs@postgresql.org> mailing list.

If your bug report has security implications and you'd prefer that it not become immediately visible in public archives, don't send it to pgsql-bugs. Security issues can be reported privately to <security@postgresql.org>.

Do not send bug reports to any of the user mailing lists, such as <pgsql-sql@postgresql.org> or <pgsql-general@postgresql.org>. These mailing lists are for answering user questions, and their subscribers normally do not wish to receive bug reports. More importantly, they are unlikely to fix them.

Also, please do *not* send reports to the developers' mailing list <pgsql-hackers@postgresql.org>. This list is for discussing the development of PostgreSQL, and it would be nice if we could keep the bug reports separate. We might choose to take up a discussion about your bug report on pgsql-hackers, if the problem needs more review.

If you have a problem with the documentation, the best place to report it is the documentation mailing list <pgsql-docs@postgresql.org>. Please be specific about what part of the documentation you are unhappy with.

9. http://www.chiark.greenend.org.uk/~sgtatham/bugs.html
10. http://www.postgresql.org/

If your bug is a portability problem on a non-supported platform, send mail to <pgsql-hackers@postgresql.org>, so we (and you) can work on porting PostgreSQL to your platform.

> **Note:** Due to the unfortunate amount of spam going around, all of the above email addresses are closed mailing lists. That is, you need to be subscribed to a list to be allowed to post on it. (You need not be subscribed to use the bug-report web form, however.) If you would like to send mail but do not want to receive list traffic, you can subscribe and set your subscription option to `nomail`. For more information send mail to <majordomo@postgresql.org> with the single word `help` in the body of the message.

I. Tutorial

Welcome to the PostgreSQL Tutorial. The following few chapters are intended to give a simple introduction to PostgreSQL, relational database concepts, and the SQL language to those who are new to any one of these aspects. We only assume some general knowledge about how to use computers. No particular Unix or programming experience is required. This part is mainly intended to give you some hands-on experience with important aspects of the PostgreSQL system. It makes no attempt to be a complete or thorough treatment of the topics it covers.

After you have worked through this tutorial you might want to move on to reading Part II to gain a more formal knowledge of the SQL language, or Part IV for information about developing applications for PostgreSQL. Those who set up and manage their own server should also read Part III.

Chapter 1. Getting Started

1.1. Installation

Before you can use PostgreSQL you need to install it, of course. It is possible that PostgreSQL is already installed at your site, either because it was included in your operating system distribution or because the system administrator already installed it. If that is the case, you should obtain information from the operating system documentation or your system administrator about how to access PostgreSQL.

If you are not sure whether PostgreSQL is already available or whether you can use it for your experimentation then you can install it yourself. Doing so is not hard and it can be a good exercise. PostgreSQL can be installed by any unprivileged user; no superuser (root) access is required.

If you are installing PostgreSQL yourself, then refer to Chapter 15 for instructions on installation, and return to this guide when the installation is complete. Be sure to follow closely the section about setting up the appropriate environment variables.

If your site administrator has not set things up in the default way, you might have some more work to do. For example, if the database server machine is a remote machine, you will need to set the `PGHOST` environment variable to the name of the database server machine. The environment variable `PGPORT` might also have to be set. The bottom line is this: if you try to start an application program and it complains that it cannot connect to the database, you should consult your site administrator or, if that is you, the documentation to make sure that your environment is properly set up. If you did not understand the preceding paragraph then read the next section.

1.2. Architectural Fundamentals

Before we proceed, you should understand the basic PostgreSQL system architecture. Understanding how the parts of PostgreSQL interact will make this chapter somewhat clearer.

In database jargon, PostgreSQL uses a client/server model. A PostgreSQL session consists of the following cooperating processes (programs):

- A server process, which manages the database files, accepts connections to the database from client applications, and performs database actions on behalf of the clients. The database server program is called `postgres`.
- The user's client (frontend) application that wants to perform database operations. Client applications can be very diverse in nature: a client could be a text-oriented tool, a graphical application, a web server that accesses the database to display web pages, or a specialized database maintenance tool. Some client applications are supplied with the PostgreSQL distribution; most are developed by users.

As is typical of client/server applications, the client and the server can be on different hosts. In that case they communicate over a TCP/IP network connection. You should keep this in mind, because the files that can be accessed on a client machine might not be accessible (or might only be accessible using a different file name) on the database server machine.

The PostgreSQL server can handle multiple concurrent connections from clients. To achieve this it starts ("forks") a new process for each connection. From that point on, the client and the new

server process communicate without intervention by the original `postgres` process. Thus, the master server process is always running, waiting for client connections, whereas client and associated server processes come and go. (All of this is of course invisible to the user. We only mention it here for completeness.)

1.3. Creating a Database

The first test to see whether you can access the database server is to try to create a database. A running PostgreSQL server can manage many databases. Typically, a separate database is used for each project or for each user.

Possibly, your site administrator has already created a database for your use. He should have told you what the name of your database is. In that case you can omit this step and skip ahead to the next section.

To create a new database, in this example named `mydb`, you use the following command:

```
$ createdb mydb
```

If this produces no response then this step was successful and you can skip over the remainder of this section.

If you see a message similar to:

```
createdb: command not found
```

then PostgreSQL was not installed properly. Either it was not installed at all or your shell's search path was not set to include it. Try calling the command with an absolute path instead:

```
$ /usr/local/pgsql/bin/createdb mydb
```

The path at your site might be different. Contact your site administrator or check the installation instructions to correct the situation.

Another response could be this:

```
createdb: could not connect to database postgres: could not connect to server: No such f
        Is the server running locally and accepting
        connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

This means that the server was not started, or it was not started where `createdb` expected it. Again, check the installation instructions or consult the administrator.

Another response could be this:

```
createdb: could not connect to database postgres: FATAL:  role "joe" does not exist
```

where your own login name is mentioned. This will happen if the administrator has not created a PostgreSQL user account for you. (PostgreSQL user accounts are distinct from operating system user accounts.) If you are the administrator, see Chapter 20 for help creating accounts. You will need to become the operating system user under which PostgreSQL was installed (usually `postgres`) to create the first user account. It could also be that you were assigned a PostgreSQL user name that is different from your operating system user name; in that case you need to use the `-U` switch or set the `PGUSER` environment variable to specify your PostgreSQL user name.

If you have a user account but it does not have the privileges required to create a database, you will see the following:

```
createdb: database creation failed: ERROR:  permission denied to create database
```

Not every user has authorization to create new databases. If PostgreSQL refuses to create databases for you then the site administrator needs to grant you permission to create databases. Consult your site administrator if this occurs. If you installed PostgreSQL yourself then you should log in for the purposes of this tutorial under the user account that you started the server as. [1]

You can also create databases with other names. PostgreSQL allows you to create any number of databases at a given site. Database names must have an alphabetic first character and are limited to 63 bytes in length. A convenient choice is to create a database with the same name as your current user name. Many tools assume that database name as the default, so it can save you some typing. To create that database, simply type:

```
$ createdb
```

If you do not want to use your database anymore you can remove it. For example, if you are the owner (creator) of the database `mydb`, you can destroy it using the following command:

```
$ dropdb mydb
```

(For this command, the database name does not default to the user account name. You always need to specify it.) This action physically removes all files associated with the database and cannot be undone, so this should only be done with a great deal of forethought.

More about `createdb` and `dropdb` can be found in createdb and dropdb respectively.

1.4. Accessing a Database

Once you have created a database, you can access it by:

- Running the PostgreSQL interactive terminal program, called *psql*, which allows you to interactively enter, edit, and execute SQL commands.
- Using an existing graphical frontend tool like pgAdmin or an office suite with ODBC or JDBC support to create and manipulate a database. These possibilities are not covered in this tutorial.
- Writing a custom application, using one of the several available language bindings. These possibilities are discussed further in Part IV.

You probably want to start up `psql` to try the examples in this tutorial. It can be activated for the `mydb` database by typing the command:

```
$ psql mydb
```

If you do not supply the database name then it will default to your user account name. You already discovered this scheme in the previous section using `createdb`.

In `psql`, you will be greeted with the following message:

1. As an explanation for why this works: PostgreSQL user names are separate from operating system user accounts. When you connect to a database, you can choose what PostgreSQL user name to connect as; if you don't, it will default to the same name as your current operating system account. As it happens, there will always be a PostgreSQL user account that has the same name as the operating system user that started the server, and it also happens that that user always has permission to create databases. Instead of logging in as that user you can also specify the `-U` option everywhere to select a PostgreSQL user name to connect as.

```
psql (9.4.1)
Type "help" for help.

mydb=>
```

The last line could also be:

```
mydb=#
```

That would mean you are a database superuser, which is most likely the case if you installed PostgreSQL yourself. Being a superuser means that you are not subject to access controls. For the purposes of this tutorial that is not important.

If you encounter problems starting `psql` then go back to the previous section. The diagnostics of `createdb` and `psql` are similar, and if the former worked the latter should work as well.

The last line printed out by `psql` is the prompt, and it indicates that `psql` is listening to you and that you can type SQL queries into a work space maintained by `psql`. Try out these commands:

```
mydb=> SELECT version();
                                   version
 ---------------------------------------------------------------------------
 PostgreSQL 9.4.1 on i586-pc-linux-gnu, compiled by GCC 2.96, 32-bit
(1 row)

mydb=> SELECT current_date;
    date
------------
 2002-08-31
(1 row)

mydb=> SELECT 2 + 2;
 ?column?
----------
        4
(1 row)
```

The `psql` program has a number of internal commands that are not SQL commands. They begin with the backslash character, "`\`". For example, you can get help on the syntax of various PostgreSQL SQL commands by typing:

```
mydb=> \h
```

To get out of `psql`, type:

```
mydb=> \q
```

and `psql` will quit and return you to your command shell. (For more internal commands, type `\?` at the `psql` prompt.) The full capabilities of `psql` are documented in psql. In this tutorial we will not use these features explicitly, but you can use them yourself when it is helpful.

Chapter 2. The SQL Language

2.1. Introduction

This chapter provides an overview of how to use SQL to perform simple operations. This tutorial is only intended to give you an introduction and is in no way a complete tutorial on SQL. Numerous books have been written on SQL, including *Understanding the New SQL* and *A Guide to the SQL Standard*. You should be aware that some PostgreSQL language features are extensions to the standard.

In the examples that follow, we assume that you have created a database named `mydb`, as described in the previous chapter, and have been able to start psql.

Examples in this manual can also be found in the PostgreSQL source distribution in the directory `src/tutorial/`. (Binary distributions of PostgreSQL might not compile these files.) To use those files, first change to that directory and run make:

```
$ cd ..../src/tutorial
$ make
```

This creates the scripts and compiles the C files containing user-defined functions and types. Then, to start the tutorial, do the following:

```
$ cd ..../tutorial
$ psql -s mydb
...

mydb=> \i basics.sql
```

The `\i` command reads in commands from the specified file. `psql`'s `-s` option puts you in single step mode which pauses before sending each statement to the server. The commands used in this section are in the file `basics.sql`.

2.2. Concepts

PostgreSQL is a *relational database management system* (RDBMS). That means it is a system for managing data stored in *relations*. Relation is essentially a mathematical term for *table*. The notion of storing data in tables is so commonplace today that it might seem inherently obvious, but there are a number of other ways of organizing databases. Files and directories on Unix-like operating systems form an example of a hierarchical database. A more modern development is the object-oriented database.

Each table is a named collection of *rows*. Each row of a given table has the same set of named *columns*, and each column is of a specific data type. Whereas columns have a fixed order in each row, it is important to remember that SQL does not guarantee the order of the rows within the table in any way (although they can be explicitly sorted for display).

Tables are grouped into databases, and a collection of databases managed by a single PostgreSQL server instance constitutes a database *cluster*.

2.3. Creating a New Table

You can create a new table by specifying the table name, along with all column names and their types:

```
CREATE TABLE weather (
    city            varchar(80),
    temp_lo         int,           -- low temperature
    temp_hi         int,           -- high temperature
    prcp            real,          -- precipitation
    date            date
);
```

You can enter this into `psql` with the line breaks. `psql` will recognize that the command is not terminated until the semicolon.

White space (i.e., spaces, tabs, and newlines) can be used freely in SQL commands. That means you can type the command aligned differently than above, or even all on one line. Two dashes ("`--`") introduce comments. Whatever follows them is ignored up to the end of the line. SQL is case insensitive about key words and identifiers, except when identifiers are double-quoted to preserve the case (not done above).

`varchar(80)` specifies a data type that can store arbitrary character strings up to 80 characters in length. `int` is the normal integer type. `real` is a type for storing single precision floating-point numbers. `date` should be self-explanatory. (Yes, the column of type `date` is also named `date`. This might be convenient or confusing — you choose.)

PostgreSQL supports the standard SQL types `int`, `smallint`, `real`, `double precision`, `char(`*N*`)`, `varchar(`*N*`)`, `date`, `time`, `timestamp`, and `interval`, as well as other types of general utility and a rich set of geometric types. PostgreSQL can be customized with an arbitrary number of user-defined data types. Consequently, type names are not key words in the syntax, except where required to support special cases in the SQL standard.

The second example will store cities and their associated geographical location:

```
CREATE TABLE cities (
    name            varchar(80),
    location        point
);
```

The `point` type is an example of a PostgreSQL-specific data type.

Finally, it should be mentioned that if you don't need a table any longer or want to recreate it differently you can remove it using the following command:

```
DROP TABLE tablename;
```

2.4. Populating a Table With Rows

The `INSERT` statement is used to populate a table with rows:

```
INSERT INTO weather VALUES ('San Francisco', 46, 50, 0.25, '1994-11-27');
```

Note that all data types use rather obvious input formats. Constants that are not simple numeric values usually must be surrounded by single quotes (’), as in the example. The date type is actually quite flexible in what it accepts, but for this tutorial we will stick to the unambiguous format shown here.

The point type requires a coordinate pair as input, as shown here:

```
INSERT INTO cities VALUES (’San Francisco’, ’(-194.0, 53.0)’);
```

The syntax used so far requires you to remember the order of the columns. An alternative syntax allows you to list the columns explicitly:

```
INSERT INTO weather (city, temp_lo, temp_hi, prcp, date)
    VALUES (’San Francisco’, 43, 57, 0.0, ’1994-11-29’);
```

You can list the columns in a different order if you wish or even omit some columns, e.g., if the precipitation is unknown:

```
INSERT INTO weather (date, city, temp_hi, temp_lo)
    VALUES (’1994-11-29’, ’Hayward’, 54, 37);
```

Many developers consider explicitly listing the columns better style than relying on the order implicitly.

Please enter all the commands shown above so you have some data to work with in the following sections.

You could also have used COPY to load large amounts of data from flat-text files. This is usually faster because the COPY command is optimized for this application while allowing less flexibility than INSERT. An example would be:

```
COPY weather FROM ’/home/user/weather.txt’;
```

where the file name for the source file must be available on the machine running the backend process, not the client, since the backend process reads the file directly. You can read more about the COPY command in COPY.

2.5. Querying a Table

To retrieve data from a table, the table is *queried*. An SQL SELECT statement is used to do this. The statement is divided into a select list (the part that lists the columns to be returned), a table list (the part that lists the tables from which to retrieve the data), and an optional qualification (the part that specifies any restrictions). For example, to retrieve all the rows of table weather, type:

```
SELECT * FROM weather;
```

Here * is a shorthand for “all columns”. [1] So the same result would be had with:

```
SELECT city, temp_lo, temp_hi, prcp, date FROM weather;
```

The output should be:

```
     city      | temp_lo | temp_hi | prcp |    date
```

1. While SELECT * is useful for off-the-cuff queries, it is widely considered bad style in production code, since adding a column to the table would change the results.

```
---------------+---------+---------+------+------------
 San Francisco |      46 |      50 | 0.25 | 1994-11-27
 San Francisco |      43 |      57 |    0 | 1994-11-29
 Hayward       |      37 |      54 |      | 1994-11-29
(3 rows)
```

You can write expressions, not just simple column references, in the select list. For example, you can do:

```
SELECT city, (temp_hi+temp_lo)/2 AS temp_avg, date FROM weather;
```

This should give:

```
     city      | temp_avg |    date
---------------+----------+------------
 San Francisco |       48 | 1994-11-27
 San Francisco |       50 | 1994-11-29
 Hayward       |       45 | 1994-11-29
(3 rows)
```

Notice how the `AS` clause is used to relabel the output column. (The `AS` clause is optional.)

A query can be "qualified" by adding a `WHERE` clause that specifies which rows are wanted. The `WHERE` clause contains a Boolean (truth value) expression, and only rows for which the Boolean expression is true are returned. The usual Boolean operators (`AND`, `OR`, and `NOT`) are allowed in the qualification. For example, the following retrieves the weather of San Francisco on rainy days:

```
SELECT * FROM weather
    WHERE city = 'San Francisco' AND prcp > 0.0;
```

Result:

```
     city      | temp_lo | temp_hi | prcp |    date
---------------+---------+---------+------+------------
 San Francisco |      46 |      50 | 0.25 | 1994-11-27
(1 row)
```

You can request that the results of a query be returned in sorted order:

```
SELECT * FROM weather
    ORDER BY city;

     city      | temp_lo | temp_hi | prcp |    date
---------------+---------+---------+------+------------
 Hayward       |      37 |      54 |      | 1994-11-29
 San Francisco |      43 |      57 |    0 | 1994-11-29
 San Francisco |      46 |      50 | 0.25 | 1994-11-27
```

In this example, the sort order isn't fully specified, and so you might get the San Francisco rows in either order. But you'd always get the results shown above if you do:

```
SELECT * FROM weather
    ORDER BY city, temp_lo;
```

You can request that duplicate rows be removed from the result of a query:

```
SELECT DISTINCT city
    FROM weather;

     city
---------------
 Hayward
 San Francisco
(2 rows)
```

Here again, the result row ordering might vary. You can ensure consistent results by using `DISTINCT` and `ORDER BY` together: [2]

```
SELECT DISTINCT city
    FROM weather
    ORDER BY city;
```

2.6. Joins Between Tables

Thus far, our queries have only accessed one table at a time. Queries can access multiple tables at once, or access the same table in such a way that multiple rows of the table are being processed at the same time. A query that accesses multiple rows of the same or different tables at one time is called a *join* query. As an example, say you wish to list all the weather records together with the location of the associated city. To do that, we need to compare the `city` column of each row of the `weather` table with the `name` column of all rows in the `cities` table, and select the pairs of rows where these values match.

> **Note:** This is only a conceptual model. The join is usually performed in a more efficient manner than actually comparing each possible pair of rows, but this is invisible to the user.

This would be accomplished by the following query:

```
SELECT *
    FROM weather, cities
    WHERE city = name;

     city      | temp_lo | temp_hi | prcp |    date    |     name      | location
---------------+---------+---------+------+------------+---------------+-----------
 San Francisco |      46 |      50 | 0.25 | 1994-11-27 | San Francisco | (-194,53)
 San Francisco |      43 |      57 |    0 | 1994-11-29 | San Francisco | (-194,53)
(2 rows)
```

Observe two things about the result set:

- There is no result row for the city of Hayward. This is because there is no matching entry in the `cities` table for Hayward, so the join ignores the unmatched rows in the `weather` table. We will see shortly how this can be fixed.

2. In some database systems, including older versions of PostgreSQL, the implementation of `DISTINCT` automatically orders the rows and so `ORDER BY` is unnecessary. But this is not required by the SQL standard, and current PostgreSQL does not guarantee that `DISTINCT` causes the rows to be ordered.

- There are two columns containing the city name. This is correct because the lists of columns from the `weather` and `cities` tables are concatenated. In practice this is undesirable, though, so you will probably want to list the output columns explicitly rather than using `*`:

```
SELECT city, temp_lo, temp_hi, prcp, date, location
    FROM weather, cities
    WHERE city = name;
```

Exercise: Attempt to determine the semantics of this query when the `WHERE` clause is omitted.

Since the columns all had different names, the parser automatically found which table they belong to. If there were duplicate column names in the two tables you'd need to *qualify* the column names to show which one you meant, as in:

```
SELECT weather.city, weather.temp_lo, weather.temp_hi,
       weather.prcp, weather.date, cities.location
    FROM weather, cities
    WHERE cities.name = weather.city;
```

It is widely considered good style to qualify all column names in a join query, so that the query won't fail if a duplicate column name is later added to one of the tables.

Join queries of the kind seen thus far can also be written in this alternative form:

```
SELECT *
    FROM weather INNER JOIN cities ON (weather.city = cities.name);
```

This syntax is not as commonly used as the one above, but we show it here to help you understand the following topics.

Now we will figure out how we can get the Hayward records back in. What we want the query to do is to scan the `weather` table and for each row to find the matching `cities` row(s). If no matching row is found we want some "empty values" to be substituted for the `cities` table's columns. This kind of query is called an *outer join*. (The joins we have seen so far are inner joins.) The command looks like this:

```
SELECT *
    FROM weather LEFT OUTER JOIN cities ON (weather.city = cities.name);

     city      | temp_lo | temp_hi | prcp |    date    |     name      | location
---------------+---------+---------+------+------------+---------------+-----------
 Hayward       |      37 |      54 |      | 1994-11-29 |               |
 San Francisco |      46 |      50 | 0.25 | 1994-11-27 | San Francisco | (-194,53)
 San Francisco |      43 |      57 |    0 | 1994-11-29 | San Francisco | (-194,53)
(3 rows)
```

This query is called a *left outer join* because the table mentioned on the left of the join operator will have each of its rows in the output at least once, whereas the table on the right will only have those rows output that match some row of the left table. When outputting a left-table row for which there is no right-table match, empty (null) values are substituted for the right-table columns.

Exercise: There are also right outer joins and full outer joins. Try to find out what those do.

We can also join a table against itself. This is called a *self join*. As an example, suppose we wish to find all the weather records that are in the temperature range of other weather records. So we need to compare the `temp_lo` and `temp_hi` columns of each `weather` row to the `temp_lo` and `temp_hi` columns of all other `weather` rows. We can do this with the following query:

```
SELECT W1.city, W1.temp_lo AS low, W1.temp_hi AS high,
    W2.city, W2.temp_lo AS low, W2.temp_hi AS high
    FROM weather W1, weather W2
    WHERE W1.temp_lo < W2.temp_lo
    AND W1.temp_hi > W2.temp_hi;

     city      | low | high |     city      | low | high
---------------+-----+------+---------------+-----+------
 San Francisco |  43 |   57 | San Francisco |  46 |   50
 Hayward       |  37 |   54 | San Francisco |  46 |   50
(2 rows)
```

Here we have relabeled the weather table as `W1` and `W2` to be able to distinguish the left and right side of the join. You can also use these kinds of aliases in other queries to save some typing, e.g.:

```
SELECT *
    FROM weather w, cities c
    WHERE w.city = c.name;
```

You will encounter this style of abbreviating quite frequently.

2.7. Aggregate Functions

Like most other relational database products, PostgreSQL supports *aggregate functions*. An aggregate function computes a single result from multiple input rows. For example, there are aggregates to compute the `count`, `sum`, `avg` (average), `max` (maximum) and `min` (minimum) over a set of rows.

As an example, we can find the highest low-temperature reading anywhere with:

```
SELECT max(temp_lo) FROM weather;

 max
-----
  46
(1 row)
```

If we wanted to know what city (or cities) that reading occurred in, we might try:

```
SELECT city FROM weather WHERE temp_lo = max(temp_lo);     WRONG
```

but this will not work since the aggregate `max` cannot be used in the `WHERE` clause. (This restriction exists because the `WHERE` clause determines which rows will be included in the aggregate calculation; so obviously it has to be evaluated before aggregate functions are computed.) However, as is often the case the query can be restated to accomplish the desired result, here by using a *subquery*:

```
SELECT city FROM weather
    WHERE temp_lo = (SELECT max(temp_lo) FROM weather);

     city
---------------
 San Francisco
(1 row)
```

This is OK because the subquery is an independent computation that computes its own aggregate separately from what is happening in the outer query.

Aggregates are also very useful in combination with `GROUP BY` clauses. For example, we can get the maximum low temperature observed in each city with:

```
SELECT city, max(temp_lo)
    FROM weather
    GROUP BY city;

     city      | max
---------------+-----
 Hayward       |  37
 San Francisco |  46
(2 rows)
```

which gives us one output row per city. Each aggregate result is computed over the table rows matching that city. We can filter these grouped rows using `HAVING`:

```
SELECT city, max(temp_lo)
    FROM weather
    GROUP BY city
    HAVING max(temp_lo) < 40;

  city   | max
---------+-----
 Hayward |  37
(1 row)
```

which gives us the same results for only the cities that have all `temp_lo` values below 40. Finally, if we only care about cities whose names begin with "`S`", we might do:

```
SELECT city, max(temp_lo)
    FROM weather
    WHERE city LIKE 'S%'❶
    GROUP BY city
    HAVING max(temp_lo) < 40;
```

❶ The `LIKE` operator does pattern matching and is explained in Section 9.7.

It is important to understand the interaction between aggregates and SQL's `WHERE` and `HAVING` clauses. The fundamental difference between `WHERE` and `HAVING` is this: `WHERE` selects input rows before groups and aggregates are computed (thus, it controls which rows go into the aggregate computation), whereas `HAVING` selects group rows after groups and aggregates are computed. Thus, the `WHERE` clause must not contain aggregate functions; it makes no sense to try to use an aggregate to determine which rows will be inputs to the aggregates. On the other hand, the `HAVING` clause always contains aggregate functions. (Strictly speaking, you are allowed to write a `HAVING` clause that doesn't use aggregates, but it's seldom useful. The same condition could be used more efficiently at the `WHERE` stage.)

In the previous example, we can apply the city name restriction in `WHERE`, since it needs no aggregate. This is more efficient than adding the restriction to `HAVING`, because we avoid doing the grouping and aggregate calculations for all rows that fail the `WHERE` check.

2.8. Updates

You can update existing rows using the `UPDATE` command. Suppose you discover the temperature readings are all off by 2 degrees after November 28. You can correct the data as follows:

```
UPDATE weather
    SET temp_hi = temp_hi - 2,  temp_lo = temp_lo - 2
    WHERE date > '1994-11-28';
```

Look at the new state of the data:

```
SELECT * FROM weather;

     city      | temp_lo | temp_hi | prcp |    date
---------------+---------+---------+------+------------
 San Francisco |      46 |      50 | 0.25 | 1994-11-27
 San Francisco |      41 |      55 |    0 | 1994-11-29
 Hayward       |      35 |      52 |      | 1994-11-29
(3 rows)
```

2.9. Deletions

Rows can be removed from a table using the `DELETE` command. Suppose you are no longer interested in the weather of Hayward. Then you can do the following to delete those rows from the table:

```
DELETE FROM weather WHERE city = 'Hayward';
```

All weather records belonging to Hayward are removed.

```
SELECT * FROM weather;

     city      | temp_lo | temp_hi | prcp |    date
---------------+---------+---------+------+------------
 San Francisco |      46 |      50 | 0.25 | 1994-11-27
 San Francisco |      41 |      55 |    0 | 1994-11-29
(2 rows)
```

One should be wary of statements of the form

```
DELETE FROM tablename;
```

Without a qualification, `DELETE` will remove *all* rows from the given table, leaving it empty. The system will not request confirmation before doing this!

Chapter 3. Advanced Features

3.1. Introduction

In the previous chapter we have covered the basics of using SQL to store and access your data in PostgreSQL. We will now discuss some more advanced features of SQL that simplify management and prevent loss or corruption of your data. Finally, we will look at some PostgreSQL extensions.

This chapter will on occasion refer to examples found in Chapter 2 to change or improve them, so it will be useful to have read that chapter. Some examples from this chapter can also be found in `advanced.sql` in the tutorial directory. This file also contains some sample data to load, which is not repeated here. (Refer to Section 2.1 for how to use the file.)

3.2. Views

Refer back to the queries in Section 2.6. Suppose the combined listing of weather records and city location is of particular interest to your application, but you do not want to type the query each time you need it. You can create a *view* over the query, which gives a name to the query that you can refer to like an ordinary table:

```
CREATE VIEW myview AS
    SELECT city, temp_lo, temp_hi, prcp, date, location
        FROM weather, cities
        WHERE city = name;

SELECT * FROM myview;
```

Making liberal use of views is a key aspect of good SQL database design. Views allow you to encapsulate the details of the structure of your tables, which might change as your application evolves, behind consistent interfaces.

Views can be used in almost any place a real table can be used. Building views upon other views is not uncommon.

3.3. Foreign Keys

Recall the `weather` and `cities` tables from Chapter 2. Consider the following problem: You want to make sure that no one can insert rows in the `weather` table that do not have a matching entry in the `cities` table. This is called maintaining the *referential integrity* of your data. In simplistic database systems this would be implemented (if at all) by first looking at the `cities` table to check if a matching record exists, and then inserting or rejecting the new `weather` records. This approach has a number of problems and is very inconvenient, so PostgreSQL can do this for you.

The new declaration of the tables would look like this:

```
CREATE TABLE cities (
        city     varchar(80) primary key,
        location point
);
```

```
CREATE TABLE weather (
        city      varchar(80) references cities(city),
        temp_lo   int,
        temp_hi   int,
        prcp      real,
        date      date
);
```

Now try inserting an invalid record:

```
INSERT INTO weather VALUES ('Berkeley', 45, 53, 0.0, '1994-11-28');
```

```
ERROR:  insert or update on table "weather" violates foreign key constraint "weather_cit
DETAIL:  Key (city)=(Berkeley) is not present in table "cities".
```

The behavior of foreign keys can be finely tuned to your application. We will not go beyond this simple example in this tutorial, but just refer you to Chapter 5 for more information. Making correct use of foreign keys will definitely improve the quality of your database applications, so you are strongly encouraged to learn about them.

3.4. Transactions

Transactions are a fundamental concept of all database systems. The essential point of a transaction is that it bundles multiple steps into a single, all-or-nothing operation. The intermediate states between the steps are not visible to other concurrent transactions, and if some failure occurs that prevents the transaction from completing, then none of the steps affect the database at all.

For example, consider a bank database that contains balances for various customer accounts, as well as total deposit balances for branches. Suppose that we want to record a payment of $100.00 from Alice's account to Bob's account. Simplifying outrageously, the SQL commands for this might look like:

```
UPDATE accounts SET balance = balance - 100.00
    WHERE name = 'Alice';
UPDATE branches SET balance = balance - 100.00
    WHERE name = (SELECT branch_name FROM accounts WHERE name = 'Alice');
UPDATE accounts SET balance = balance + 100.00
    WHERE name = 'Bob';
UPDATE branches SET balance = balance + 100.00
    WHERE name = (SELECT branch_name FROM accounts WHERE name = 'Bob');
```

The details of these commands are not important here; the important point is that there are several separate updates involved to accomplish this rather simple operation. Our bank's officers will want to be assured that either all these updates happen, or none of them happen. It would certainly not do for a system failure to result in Bob receiving $100.00 that was not debited from Alice. Nor would Alice long remain a happy customer if she was debited without Bob being credited. We need a guarantee that if something goes wrong partway through the operation, none of the steps executed so far will take effect. Grouping the updates into a *transaction* gives us this guarantee. A transaction is said to be *atomic*: from the point of view of other transactions, it either happens completely or not at all.

We also want a guarantee that once a transaction is completed and acknowledged by the database system, it has indeed been permanently recorded and won't be lost even if a crash ensues shortly thereafter. For example, if we are recording a cash withdrawal by Bob, we do not want any chance that the debit to his account will disappear in a crash just after he walks out the bank door. A transactional database guarantees that all the updates made by a transaction are logged in permanent storage (i.e., on disk) before the transaction is reported complete.

Another important property of transactional databases is closely related to the notion of atomic updates: when multiple transactions are running concurrently, each one should not be able to see the incomplete changes made by others. For example, if one transaction is busy totalling all the branch balances, it would not do for it to include the debit from Alice's branch but not the credit to Bob's branch, nor vice versa. So transactions must be all-or-nothing not only in terms of their permanent effect on the database, but also in terms of their visibility as they happen. The updates made so far by an open transaction are invisible to other transactions until the transaction completes, whereupon all the updates become visible simultaneously.

In PostgreSQL, a transaction is set up by surrounding the SQL commands of the transaction with `BEGIN` and `COMMIT` commands. So our banking transaction would actually look like:

```
BEGIN;
UPDATE accounts SET balance = balance - 100.00
    WHERE name = 'Alice';
-- etc etc
COMMIT;
```

If, partway through the transaction, we decide we do not want to commit (perhaps we just noticed that Alice's balance went negative), we can issue the command `ROLLBACK` instead of `COMMIT`, and all our updates so far will be canceled.

PostgreSQL actually treats every SQL statement as being executed within a transaction. If you do not issue a `BEGIN` command, then each individual statement has an implicit `BEGIN` and (if successful) `COMMIT` wrapped around it. A group of statements surrounded by `BEGIN` and `COMMIT` is sometimes called a *transaction block*.

> **Note:** Some client libraries issue `BEGIN` and `COMMIT` commands automatically, so that you might get the effect of transaction blocks without asking. Check the documentation for the interface you are using.

It's possible to control the statements in a transaction in a more granular fashion through the use of *savepoints*. Savepoints allow you to selectively discard parts of the transaction, while committing the rest. After defining a savepoint with `SAVEPOINT`, you can if needed roll back to the savepoint with `ROLLBACK TO`. All the transaction's database changes between defining the savepoint and rolling back to it are discarded, but changes earlier than the savepoint are kept.

After rolling back to a savepoint, it continues to be defined, so you can roll back to it several times. Conversely, if you are sure you won't need to roll back to a particular savepoint again, it can be released, so the system can free some resources. Keep in mind that either releasing or rolling back to a savepoint will automatically release all savepoints that were defined after it.

All this is happening within the transaction block, so none of it is visible to other database sessions. When and if you commit the transaction block, the committed actions become visible as a unit to other sessions, while the rolled-back actions never become visible at all.

Remembering the bank database, suppose we debit $100.00 from Alice's account, and credit Bob's account, only to find later that we should have credited Wally's account. We could do it using savepoints like this:

```
BEGIN;
UPDATE accounts SET balance = balance - 100.00
    WHERE name = 'Alice';
SAVEPOINT my_savepoint;
UPDATE accounts SET balance = balance + 100.00
    WHERE name = 'Bob';
-- oops ... forget that and use Wally's account
ROLLBACK TO my_savepoint;
UPDATE accounts SET balance = balance + 100.00
    WHERE name = 'Wally';
COMMIT;
```

This example is, of course, oversimplified, but there's a lot of control possible in a transaction block through the use of savepoints. Moreover, `ROLLBACK TO` is the only way to regain control of a transaction block that was put in aborted state by the system due to an error, short of rolling it back completely and starting again.

3.5. Window Functions

A *window function* performs a calculation across a set of table rows that are somehow related to the current row. This is comparable to the type of calculation that can be done with an aggregate function. But unlike regular aggregate functions, use of a window function does not cause rows to become grouped into a single output row — the rows retain their separate identities. Behind the scenes, the window function is able to access more than just the current row of the query result.

Here is an example that shows how to compare each employee's salary with the average salary in his or her department:

```
SELECT depname, empno, salary, avg(salary) OVER (PARTITION BY depname) FROM empsalary;

  depname  | empno | salary |          avg
-----------+-------+--------+-----------------------
 develop   |    11 |   5200 | 5020.0000000000000000
 develop   |     7 |   4200 | 5020.0000000000000000
 develop   |     9 |   4500 | 5020.0000000000000000
 develop   |     8 |   6000 | 5020.0000000000000000
 develop   |    10 |   5200 | 5020.0000000000000000
 personnel |     5 |   3500 | 3700.0000000000000000
 personnel |     2 |   3900 | 3700.0000000000000000
 sales     |     3 |   4800 | 4866.6666666666666667
 sales     |     1 |   5000 | 4866.6666666666666667
 sales     |     4 |   4800 | 4866.6666666666666667
(10 rows)
```

The first three output columns come directly from the table `empsalary`, and there is one output row for each row in the table. The fourth column represents an average taken across all the table rows that have the same `depname` value as the current row. (This actually is the same function as the regular `avg` aggregate function, but the `OVER` clause causes it to be treated as a window function and computed across an appropriate set of rows.)

A window function call always contains an OVER clause directly following the window function's name and argument(s). This is what syntactically distinguishes it from a regular function or aggregate function. The OVER clause determines exactly how the rows of the query are split up for processing by the window function. The PARTITION BY list within OVER specifies dividing the rows into groups, or partitions, that share the same values of the PARTITION BY expression(s). For each row, the window function is computed across the rows that fall into the same partition as the current row.

You can also control the order in which rows are processed by window functions using ORDER BY within OVER. (The window ORDER BY does not even have to match the order in which the rows are output.) Here is an example:

```
SELECT depname, empno, salary,
       rank() OVER (PARTITION BY depname ORDER BY salary DESC)
FROM empsalary;

  depname  | empno | salary | rank
-----------+-------+--------+------
 develop   |     8 |   6000 |    1
 develop   |    10 |   5200 |    2
 develop   |    11 |   5200 |    2
 develop   |     9 |   4500 |    4
 develop   |     7 |   4200 |    5
 personnel |     2 |   3900 |    1
 personnel |     5 |   3500 |    2
 sales     |     1 |   5000 |    1
 sales     |     4 |   4800 |    2
 sales     |     3 |   4800 |    2
(10 rows)
```

As shown here, the rank function produces a numerical rank within the current row's partition for each distinct ORDER BY value, in the order defined by the ORDER BY clause. rank needs no explicit parameter, because its behavior is entirely determined by the OVER clause.

The rows considered by a window function are those of the "virtual table" produced by the query's FROM clause as filtered by its WHERE, GROUP BY, and HAVING clauses if any. For example, a row removed because it does not meet the WHERE condition is not seen by any window function. A query can contain multiple window functions that slice up the data in different ways by means of different OVER clauses, but they all act on the same collection of rows defined by this virtual table.

We already saw that ORDER BY can be omitted if the ordering of rows is not important. It is also possible to omit PARTITION BY, in which case there is just one partition containing all the rows.

There is another important concept associated with window functions: for each row, there is a set of rows within its partition called its *window frame*. Many (but not all) window functions act only on the rows of the window frame, rather than of the whole partition. By default, if ORDER BY is supplied then the frame consists of all rows from the start of the partition up through the current row, plus any following rows that are equal to the current row according to the ORDER BY clause. When ORDER BY is omitted the default frame consists of all rows in the partition. [1] Here is an example using sum:

```
SELECT salary, sum(salary) OVER () FROM empsalary;

 salary |  sum
--------+-------
   5200 | 47100
   5000 | 47100
```

1. There are options to define the window frame in other ways, but this tutorial does not cover them. See Section 4.2.8 for details.

```
   3500 | 47100
   4800 | 47100
   3900 | 47100
   4200 | 47100
   4500 | 47100
   4800 | 47100
   6000 | 47100
   5200 | 47100
(10 rows)
```

Above, since there is no `ORDER BY` in the `OVER` clause, the window frame is the same as the partition, which for lack of `PARTITION BY` is the whole table; in other words each sum is taken over the whole table and so we get the same result for each output row. But if we add an `ORDER BY` clause, we get very different results:

```
SELECT salary, sum(salary) OVER (ORDER BY salary) FROM empsalary;
```

```
 salary |  sum
--------+-------
   3500 |  3500
   3900 |  7400
   4200 | 11600
   4500 | 16100
   4800 | 25700
   4800 | 25700
   5000 | 30700
   5200 | 41100
   5200 | 41100
   6000 | 47100
(10 rows)
```

Here the sum is taken from the first (lowest) salary up through the current one, including any duplicates of the current one (notice the results for the duplicated salaries).

Window functions are permitted only in the `SELECT` list and the `ORDER BY` clause of the query. They are forbidden elsewhere, such as in `GROUP BY`, `HAVING` and `WHERE` clauses. This is because they logically execute after the processing of those clauses. Also, window functions execute after regular aggregate functions. This means it is valid to include an aggregate function call in the arguments of a window function, but not vice versa.

If there is a need to filter or group rows after the window calculations are performed, you can use a sub-select. For example:

```
SELECT depname, empno, salary, enroll_date
FROM
  (SELECT depname, empno, salary, enroll_date,
          rank() OVER (PARTITION BY depname ORDER BY salary DESC, empno) AS pos
     FROM empsalary
  ) AS ss
WHERE pos < 3;
```

The above query only shows the rows from the inner query having `rank` less than 3.

When a query involves multiple window functions, it is possible to write out each one with a separate `OVER` clause, but this is duplicative and error-prone if the same windowing behavior is wanted for several functions. Instead, each windowing behavior can be named in a `WINDOW` clause and then referenced in `OVER`. For example:

```
SELECT sum(salary) OVER w, avg(salary) OVER w
  FROM empsalary
  WINDOW w AS (PARTITION BY depname ORDER BY salary DESC);
```

More details about window functions can be found in Section 4.2.8, Section 9.21, Section 7.2.4, and the SELECT reference page.

3.6. Inheritance

Inheritance is a concept from object-oriented databases. It opens up interesting new possibilities of database design.

Let's create two tables: A table `cities` and a table `capitals`. Naturally, capitals are also cities, so you want some way to show the capitals implicitly when you list all cities. If you're really clever you might invent some scheme like this:

```
CREATE TABLE capitals (
  name       text,
  population real,
  altitude   int,    -- (in ft)
  state      char(2)
);

CREATE TABLE non_capitals (
  name       text,
  population real,
  altitude   int     -- (in ft)
);

CREATE VIEW cities AS
  SELECT name, population, altitude FROM capitals
    UNION
  SELECT name, population, altitude FROM non_capitals;
```

This works OK as far as querying goes, but it gets ugly when you need to update several rows, for one thing.

A better solution is this:

```
CREATE TABLE cities (
  name       text,
  population real,
  altitude   int     -- (in ft)
);

CREATE TABLE capitals (
  state      char(2)
) INHERITS (cities);
```

In this case, a row of `capitals` *inherits* all columns (`name`, `population`, and `altitude`) from its *parent*, `cities`. The type of the column `name` is `text`, a native PostgreSQL type for variable length

character strings. State capitals have an extra column, `state`, that shows their state. In PostgreSQL, a table can inherit from zero or more other tables.

For example, the following query finds the names of all cities, including state capitals, that are located at an altitude over 500 feet:

```
SELECT name, altitude
  FROM cities
  WHERE altitude > 500;
```

which returns:

```
   name    | altitude
-----------+----------
 Las Vegas |     2174
 Mariposa  |     1953
 Madison   |      845
(3 rows)
```

On the other hand, the following query finds all the cities that are not state capitals and are situated at an altitude over 500 feet:

```
SELECT name, altitude
    FROM ONLY cities
    WHERE altitude > 500;

   name    | altitude
-----------+----------
 Las Vegas |     2174
 Mariposa  |     1953
(2 rows)
```

Here the `ONLY` before `cities` indicates that the query should be run over only the `cities` table, and not tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE`, and `DELETE` — support this `ONLY` notation.

> **Note:** Although inheritance is frequently useful, it has not been integrated with unique constraints or foreign keys, which limits its usefulness. See Section 5.8 for more detail.

3.7. Conclusion

PostgreSQL has many features not touched upon in this tutorial introduction, which has been oriented toward newer users of SQL. These features are discussed in more detail in the remainder of this book.

If you feel you need more introductory material, please visit the PostgreSQL web site[2] for links to more resources.

2. http://www.postgresql.org

II. The SQL Language

This part describes the use of the SQL language in PostgreSQL. We start with describing the general syntax of SQL, then explain how to create the structures to hold data, how to populate the database, and how to query it. The middle part lists the available data types and functions for use in SQL commands. The rest treats several aspects that are important for tuning a database for optimal performance.

The information in this part is arranged so that a novice user can follow it start to end to gain a full understanding of the topics without having to refer forward too many times. The chapters are intended to be self-contained, so that advanced users can read the chapters individually as they choose. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

Readers of this part should know how to connect to a PostgreSQL database and issue SQL commands. Readers that are unfamiliar with these issues are encouraged to read Part I first. SQL commands are typically entered using the PostgreSQL interactive terminal psql, but other programs that have similar functionality can be used as well.

Chapter 4. SQL Syntax

This chapter describes the syntax of SQL. It forms the foundation for understanding the following chapters which will go into detail about how SQL commands are applied to define and modify data.

We also advise users who are already familiar with SQL to read this chapter carefully because it contains several rules and concepts that are implemented inconsistently among SQL databases or that are specific to PostgreSQL.

4.1. Lexical Structure

SQL input consists of a sequence of *commands*. A command is composed of a sequence of *tokens*, terminated by a semicolon (";"). The end of the input stream also terminates a command. Which tokens are valid depends on the syntax of the particular command.

A token can be a *key word*, an *identifier*, a *quoted identifier*, a *literal* (or constant), or a special character symbol. Tokens are normally separated by whitespace (space, tab, newline), but need not be if there is no ambiguity (which is generally only the case if a special character is adjacent to some other token type).

For example, the following is (syntactically) valid SQL input:

```
SELECT * FROM MY_TABLE;
UPDATE MY_TABLE SET A = 5;
INSERT INTO MY_TABLE VALUES (3, 'hi there');
```

This is a sequence of three commands, one per line (although this is not required; more than one command can be on a line, and commands can usefully be split across lines).

Additionally, *comments* can occur in SQL input. They are not tokens, they are effectively equivalent to whitespace.

The SQL syntax is not very consistent regarding what tokens identify commands and which are operands or parameters. The first few tokens are generally the command name, so in the above example we would usually speak of a "SELECT", an "UPDATE", and an "INSERT" command. But for instance the `UPDATE` command always requires a `SET` token to appear in a certain position, and this particular variation of `INSERT` also requires a `VALUES` in order to be complete. The precise syntax rules for each command are described in Part VI.

4.1.1. Identifiers and Key Words

Tokens such as `SELECT`, `UPDATE`, or `VALUES` in the example above are examples of *key words*, that is, words that have a fixed meaning in the SQL language. The tokens `MY_TABLE` and `A` are examples of *identifiers*. They identify names of tables, columns, or other database objects, depending on the command they are used in. Therefore they are sometimes simply called "names". Key words and identifiers have the same lexical structure, meaning that one cannot know whether a token is an identifier or a key word without knowing the language. A complete list of key words can be found in Appendix C.

SQL identifiers and key words must begin with a letter (`a-z`, but also letters with diacritical marks and non-Latin letters) or an underscore (_). Subsequent characters in an identifier or key word can be letters, underscores, digits (`0-9`), or dollar signs (`$`). Note that dollar signs are not allowed in identifiers according to the letter of the SQL standard, so their use might render applications less portable. The

SQL standard will not define a key word that contains digits or starts or ends with an underscore, so identifiers of this form are safe against possible conflict with future extensions of the standard.

The system uses no more than NAMEDATALEN-1 bytes of an identifier; longer names can be written in commands, but they will be truncated. By default, NAMEDATALEN is 64 so the maximum identifier length is 63 bytes. If this limit is problematic, it can be raised by changing the NAMEDATALEN constant in src/include/pg_config_manual.h.

Key words and unquoted identifiers are case insensitive. Therefore:

```
UPDATE MY_TABLE SET A = 5;
```

can equivalently be written as:

```
uPDaTE my_TabLE SeT a = 5;
```

A convention often used is to write key words in upper case and names in lower case, e.g.:

```
UPDATE my_table SET a = 5;
```

There is a second kind of identifier: the *delimited identifier* or *quoted identifier*. It is formed by enclosing an arbitrary sequence of characters in double-quotes ("). A delimited identifier is always an identifier, never a key word. So "select" could be used to refer to a column or table named "select", whereas an unquoted select would be taken as a key word and would therefore provoke a parse error when used where a table or column name is expected. The example can be written with quoted identifiers like this:

```
UPDATE "my_table" SET "a" = 5;
```

Quoted identifiers can contain any character, except the character with code zero. (To include a double quote, write two double quotes.) This allows constructing table or column names that would otherwise not be possible, such as ones containing spaces or ampersands. The length limitation still applies.

A variant of quoted identifiers allows including escaped Unicode characters identified by their code points. This variant starts with U& (upper or lower case U followed by ampersand) immediately before the opening double quote, without any spaces in between, for example U&"foo". (Note that this creates an ambiguity with the operator &. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the identifier "data" could be written as

```
U&"d\0061t\+000061"
```

The following less trivial example writes the Russian word "slon" (elephant) in Cyrillic letters:

```
U&"\0441\043B\043E\043D"
```

If a different escape character than backslash is desired, it can be specified using the UESCAPE clause after the string, for example:

```
U&"d!0061t!+000061" UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character. Note that the escape character is written in single quotes, not double quotes.

To include the escape character in the identifier literally, write it twice.

The Unicode escape syntax works only when the server encoding is `UTF8`. When other server encodings are used, only code points in the ASCII range (up to `\007F`) can be specified. Both the 4-digit and the 6-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than U+FFFF, although the availability of the 6-digit form technically makes this unnecessary. (Surrogate pairs are not stored directly, but combined into a single code point that is then encoded in UTF-8.)

Quoting an identifier also makes it case-sensitive, whereas unquoted names are always folded to lower case. For example, the identifiers `FOO`, `foo`, and `"foo"` are considered the same by PostgreSQL, but `"Foo"` and `"FOO"` are different from these three and each other. (The folding of unquoted names to lower case in PostgreSQL is incompatible with the SQL standard, which says that unquoted names should be folded to upper case. Thus, `foo` should be equivalent to `"FOO"` not `"foo"` according to the standard. If you want to write portable applications you are advised to always quote a particular name or never quote it.)

4.1.2. Constants

There are three kinds of *implicitly-typed constants* in PostgreSQL: strings, bit strings, and numbers. Constants can also be specified with explicit types, which can enable more accurate representation and more efficient handling by the system. These alternatives are discussed in the following subsections.

4.1.2.1. String Constants

A string constant in SQL is an arbitrary sequence of characters bounded by single quotes (`'`), for example `'This is a string'`. To include a single-quote character within a string constant, write two adjacent single quotes, e.g., `'Dianne''s horse'`. Note that this is *not* the same as a double-quote character (`"`).

Two string constants that are only separated by whitespace *with at least one newline* are concatenated and effectively treated as if the string had been written as one constant. For example:

```
SELECT 'foo'
'bar';
```

is equivalent to:

```
SELECT 'foobar';
```

but:

```
SELECT 'foo'      'bar';
```

is not valid syntax. (This slightly bizarre behavior is specified by SQL; PostgreSQL is following the standard.)

4.1.2.2. String Constants with C-style Escapes

PostgreSQL also accepts "escape" string constants, which are an extension to the SQL standard. An escape string constant is specified by writing the letter `E` (upper or lower case) just before the opening single quote, e.g., `E'foo'`. (When continuing an escape string constant across lines, write `E` only before the first opening quote.) Within an escape string, a backslash character (`\`) begins a C-like *backslash escape* sequence, in which the combination of backslash and following character(s) represent a special byte value, as shown in Table 4-1.

Table 4-1. Backslash Escape Sequences

Backslash Escape Sequence	Interpretation
`\b`	backspace
`\f`	form feed
`\n`	newline
`\r`	carriage return
`\t`	tab
`\`*o*, `\`*oo*, `\`*ooo* (*o* = 0 - 7)	octal byte value
`\x`*h*, `\x`*hh* (*h* = 0 - 9, A - F)	hexadecimal byte value
`\u`*xxxx*, `\U`*xxxxxxxx* (*x* = 0 - 9, A - F)	16 or 32-bit hexadecimal Unicode character value

Any other character following a backslash is taken literally. Thus, to include a backslash character, write two backslashes (`\\`). Also, a single quote can be included in an escape string by writing `\'`, in addition to the normal way of `''`.

It is your responsibility that the byte sequences you create, especially when using the octal or hexadecimal escapes, compose valid characters in the server character set encoding. When the server encoding is UTF-8, then the Unicode escapes or the alternative Unicode escape syntax, explained in Section 4.1.2.3, should be used instead. (The alternative would be doing the UTF-8 encoding by hand and writing out the bytes, which would be very cumbersome.)

The Unicode escape syntax works fully only when the server encoding is `UTF8`. When other server encodings are used, only code points in the ASCII range (up to `\u007F`) can be specified. Both the 4-digit and the 8-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than U+FFFF, although the availability of the 8-digit form technically makes this unnecessary. (When surrogate pairs are used when the server encoding is `UTF8`, they are first combined into a single code point that is then encoded in UTF-8.)

> **Caution**
>
> If the configuration parameter standard_conforming_strings is `off`, then PostgreSQL recognizes backslash escapes in both regular and escape string constants. However, as of PostgreSQL 9.1, the default is `on`, meaning that backslash escapes are recognized only in escape string constants. This behavior is more standards-compliant, but might break applications which rely on the historical behavior, where backslash escapes were always recognized. As a workaround, you can set this parameter to `off`, but it is better to migrate away from using backslash escapes. If you need to use a backslash escape to represent a special character, write the string constant with an `E`.
>
> In addition to `standard_conforming_strings`, the configuration parameters escape_string_warning and backslash_quote govern treatment of backslashes in string constants.

The character with the code zero cannot be in a string constant.

4.1.2.3. String Constants with Unicode Escapes

PostgreSQL also supports another type of escape syntax for strings that allows specifying arbitrary Unicode characters by code point. A Unicode escape string constant starts with `U&` (upper or lower case letter U followed by ampersand) immediately before the opening quote, without any spaces in between, for example `U&'foo'`. (Note that this creates an ambiguity with the operator `&`. Use spaces around the operator to avoid this problem.) Inside the quotes, Unicode characters can be specified in escaped form by writing a backslash followed by the four-digit hexadecimal code point number or alternatively a backslash followed by a plus sign followed by a six-digit hexadecimal code point number. For example, the string `'data'` could be written as

```
U&'d\0061t\+000061'
```

The following less trivial example writes the Russian word "slon" (elephant) in Cyrillic letters:

```
U&'\0441\043B\043E\043D'
```

If a different escape character than backslash is desired, it can be specified using the `UESCAPE` clause after the string, for example:

```
U&'d!0061t!+000061' UESCAPE '!'
```

The escape character can be any single character other than a hexadecimal digit, the plus sign, a single quote, a double quote, or a whitespace character.

The Unicode escape syntax works only when the server encoding is `UTF8`. When other server encodings are used, only code points in the ASCII range (up to `\007F`) can be specified. Both the 4-digit and the 6-digit form can be used to specify UTF-16 surrogate pairs to compose characters with code points larger than U+FFFF, although the availability of the 6-digit form technically makes this unnecessary. (When surrogate pairs are used when the server encoding is `UTF8`, they are first combined into a single code point that is then encoded in UTF-8.)

Also, the Unicode escape syntax for string constants only works when the configuration parameter standard_conforming_strings is turned on. This is because otherwise this syntax could confuse clients that parse the SQL statements to the point that it could lead to SQL injections and similar security issues. If the parameter is set to off, this syntax will be rejected with an error message.

To include the escape character in the string literally, write it twice.

4.1.2.4. Dollar-quoted String Constants

While the standard syntax for specifying string constants is usually convenient, it can be difficult to understand when the desired string contains many single quotes or backslashes, since each of those must be doubled. To allow more readable queries in such situations, PostgreSQL provides another way, called "dollar quoting", to write string constants. A dollar-quoted string constant consists of a dollar sign (`$`), an optional "tag" of zero or more characters, another dollar sign, an arbitrary sequence of characters that makes up the string content, a dollar sign, the same tag that began this dollar quote, and a dollar sign. For example, here are two different ways to specify the string "Dianne's horse" using dollar quoting:

```
$$Dianne's horse$$
```

```
$SomeTag$Dianne's horse$SomeTag$
```

Notice that inside the dollar-quoted string, single quotes can be used without needing to be escaped. Indeed, no characters inside a dollar-quoted string are ever escaped: the string content is always written literally. Backslashes are not special, and neither are dollar signs, unless they are part of a sequence matching the opening tag.

It is possible to nest dollar-quoted string constants by choosing different tags at each nesting level. This is most commonly used in writing function definitions. For example:

```
$function$
BEGIN
    RETURN ($1 ~ $q$[\t\r\n\v\\]$q$);
END;
$function$
```

Here, the sequence `$q$[\t\r\n\v\\]$q$` represents a dollar-quoted literal string `[\t\r\n\v\\]`, which will be recognized when the function body is executed by PostgreSQL. But since the sequence does not match the outer dollar quoting delimiter `$function$`, it is just some more characters within the constant so far as the outer string is concerned.

The tag, if any, of a dollar-quoted string follows the same rules as an unquoted identifier, except that it cannot contain a dollar sign. Tags are case sensitive, so `$tag$String content$tag$` is correct, but `$TAG$String content$tag$` is not.

A dollar-quoted string that follows a keyword or identifier must be separated from it by whitespace; otherwise the dollar quoting delimiter would be taken as part of the preceding identifier.

Dollar quoting is not part of the SQL standard, but it is often a more convenient way to write complicated string literals than the standard-compliant single quote syntax. It is particularly useful when representing string constants inside other constants, as is often needed in procedural function definitions. With single-quote syntax, each backslash in the above example would have to be written as four backslashes, which would be reduced to two backslashes in parsing the original string constant, and then to one when the inner string constant is re-parsed during function execution.

4.1.2.5. Bit-string Constants

Bit-string constants look like regular string constants with a `B` (upper or lower case) immediately before the opening quote (no intervening whitespace), e.g., `B'1001'`. The only characters allowed within bit-string constants are `0` and `1`.

Alternatively, bit-string constants can be specified in hexadecimal notation, using a leading `X` (upper or lower case), e.g., `X'1FF'`. This notation is equivalent to a bit-string constant with four binary digits for each hexadecimal digit.

Both forms of bit-string constant can be continued across lines in the same way as regular string constants. Dollar quoting cannot be used in a bit-string constant.

4.1.2.6. Numeric Constants

Numeric constants are accepted in these general forms:

digits
digits.[*digits*][e[+-]*digits*]
[*digits*].*digits*[e[+-]*digits*]
*digits*e[+-]*digits*

where *digits* is one or more decimal digits (0 through 9). At least one digit must be before or after the decimal point, if one is used. At least one digit must follow the exponent marker (e), if one is present. There cannot be any spaces or other characters embedded in the constant. Note that any leading plus or minus sign is not actually considered part of the constant; it is an operator applied to the constant.

These are some examples of valid numeric constants:

42
3.5
4.
.001
5e2
1.925e-3

A numeric constant that contains neither a decimal point nor an exponent is initially presumed to be type integer if its value fits in type integer (32 bits); otherwise it is presumed to be type bigint if its value fits in type bigint (64 bits); otherwise it is taken to be type numeric. Constants that contain decimal points and/or exponents are always initially presumed to be type numeric.

The initially assigned data type of a numeric constant is just a starting point for the type resolution algorithms. In most cases the constant will be automatically coerced to the most appropriate type depending on context. When necessary, you can force a numeric value to be interpreted as a specific data type by casting it. For example, you can force a numeric value to be treated as type real (float4) by writing:

```
REAL '1.23'  -- string style
1.23::REAL   -- PostgreSQL (historical) style
```

These are actually just special cases of the general casting notations discussed next.

4.1.2.7. Constants of Other Types

A constant of an *arbitrary* type can be entered using any one of the following notations:

```
type 'string'
'string'::type
CAST ( 'string' AS type )
```

The string constant's text is passed to the input conversion routine for the type called *type*. The result is a constant of the indicated type. The explicit type cast can be omitted if there is no ambiguity as to the type the constant must be (for example, when it is assigned directly to a table column), in which case it is automatically coerced.

The string constant can be written using either regular SQL notation or dollar-quoting.

It is also possible to specify a type coercion using a function-like syntax:

```
typename ( 'string' )
```

but not all type names can be used in this way; see Section 4.2.9 for details.

The ::, CAST(), and function-call syntaxes can also be used to specify run-time type conversions of arbitrary expressions, as discussed in Section 4.2.9. To avoid syntactic ambiguity, the *type 'string'* syntax can only be used to specify the type of a simple literal constant. Another restriction on the *type*

'*string*' syntax is that it does not work for array types; use :: or CAST() to specify the type of an array constant.

The CAST() syntax conforms to SQL. The *type* '*string*' syntax is a generalization of the standard: SQL specifies this syntax only for a few data types, but PostgreSQL allows it for all types. The syntax with :: is historical PostgreSQL usage, as is the function-call syntax.

4.1.3. Operators

An operator name is a sequence of up to NAMEDATALEN-1 (63 by default) characters from the following list:

+ - * / < > = ~ ! @ # % ^ & | ` ?

There are a few restrictions on operator names, however:

- -- and /* cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multiple-character operator name cannot end in + or -, unless the name also contains at least one of these characters:

  ~ ! @ # % ^ & | ` ?

  For example, @- is an allowed operator name, but *- is not. This restriction allows PostgreSQL to parse SQL-compliant queries without requiring spaces between tokens.

When working with non-SQL-standard operator names, you will usually need to separate adjacent operators with spaces to avoid ambiguity. For example, if you have defined a left unary operator named @, you cannot write X*@Y; you must write X* @Y to ensure that PostgreSQL reads it as two operator names not one.

4.1.4. Special Characters

Some characters that are not alphanumeric have a special meaning that is different from being an operator. Details on the usage can be found at the location where the respective syntax element is described. This section only exists to advise the existence and summarize the purposes of these characters.

- A dollar sign ($) followed by digits is used to represent a positional parameter in the body of a function definition or a prepared statement. In other contexts the dollar sign can be part of an identifier or a dollar-quoted string constant.
- Parentheses (()) have their usual meaning to group expressions and enforce precedence. In some cases parentheses are required as part of the fixed syntax of a particular SQL command.
- Brackets ([]) are used to select the elements of an array. See Section 8.15 for more information on arrays.
- Commas (,) are used in some syntactical constructs to separate the elements of a list.

- The semicolon (;) terminates an SQL command. It cannot appear anywhere within a command, except within a string constant or quoted identifier.
- The colon (:) is used to select "slices" from arrays. (See Section 8.15.) In certain SQL dialects (such as Embedded SQL), the colon is used to prefix variable names.
- The asterisk (*) is used in some contexts to denote all the fields of a table row or composite value. It also has a special meaning when used as the argument of an aggregate function, namely that the aggregate does not require any explicit parameter.
- The period (.) is used in numeric constants, and to separate schema, table, and column names.

4.1.5. Comments

A comment is a sequence of characters beginning with double dashes and extending to the end of the line, e.g.:

```
-- This is a standard SQL comment
```

Alternatively, C-style block comments can be used:

```
/* multiline comment
 * with nesting: /* nested block comment */
 */
```

where the comment begins with /* and extends to the matching occurrence of */. These block comments nest, as specified in the SQL standard but unlike C, so that one can comment out larger blocks of code that might contain existing block comments.

A comment is removed from the input stream before further syntax analysis and is effectively replaced by whitespace.

4.1.6. Operator Precedence

Table 4-2 shows the precedence and associativity of the operators in PostgreSQL. Most operators have the same precedence and are left-associative. The precedence and associativity of the operators is hard-wired into the parser. This can lead to non-intuitive behavior; for example the Boolean operators < and > have a different precedence than the Boolean operators <= and >=. Also, you will sometimes need to add parentheses when using combinations of binary and unary operators. For instance:

```
SELECT 5 ! - 6;
```

will be parsed as:

```
SELECT 5 ! (- 6);
```

because the parser has no idea — until it is too late — that ! is defined as a postfix operator, not an infix one. To get the desired behavior in this case, you must write:

```
SELECT (5 !) - 6;
```

This is the price one pays for extensibility.

Table 4-2. Operator Precedence (decreasing)

Operator/Element	Associativity	Description
.	left	table/column name separator
::	left	PostgreSQL-style typecast
[ ]	left	array element selection
+ -	right	unary plus, unary minus
^	left	exponentiation
* / %	left	multiplication, division, modulo
+ -	left	addition, subtraction
IS		IS TRUE, IS FALSE, IS NULL, etc
ISNULL		test for null
NOTNULL		test for not null
(any other)	left	all other native and user-defined operators
IN		set membership
BETWEEN		range containment
OVERLAPS		time interval overlap
LIKE ILIKE SIMILAR		string pattern matching
< >		less than, greater than
=	right	equality, assignment
NOT	right	logical negation
AND	left	logical conjunction
OR	left	logical disjunction

Note that the operator precedence rules also apply to user-defined operators that have the same names as the built-in operators mentioned above. For example, if you define a "+" operator for some custom data type it will have the same precedence as the built-in "+" operator, no matter what yours does.

When a schema-qualified operator name is used in the OPERATOR syntax, as for example in:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

the OPERATOR construct is taken to have the default precedence shown in Table 4-2 for "any other" operator. This is true no matter which specific operator appears inside OPERATOR().

4.2. Value Expressions

Value expressions are used in a variety of contexts, such as in the target list of the SELECT command, as new column values in INSERT or UPDATE, or in search conditions in a number of commands. The result of a value expression is sometimes called a *scalar*, to distinguish it from the result of a table expression (which is a table). Value expressions are therefore also called *scalar expressions* (or even simply *expressions*). The expression syntax allows the calculation of values from primitive parts using arithmetic, logical, set, and other operations.

A value expression is one of the following:

- A constant or literal value
- A column reference
- A positional parameter reference, in the body of a function definition or prepared statement
- A subscripted expression
- A field selection expression
- An operator invocation
- A function call
- An aggregate expression
- A window function call
- A type cast
- A collation expression
- A scalar subquery
- An array constructor
- A row constructor
- Another value expression in parentheses (used to group subexpressions and override precedence)

In addition to this list, there are a number of constructs that can be classified as an expression but do not follow any general syntax rules. These generally have the semantics of a function or operator and are explained in the appropriate location in Chapter 9. An example is the `IS NULL` clause.

We have already discussed constants in Section 4.1.2. The following sections discuss the remaining options.

4.2.1. Column References

A column can be referenced in the form:

```
correlation.columnname
```

correlation is the name of a table (possibly qualified with a schema name), or an alias for a table defined by means of a `FROM` clause. The correlation name and separating dot can be omitted if the column name is unique across all the tables being used in the current query. (See also Chapter 7.)

4.2.2. Positional Parameters

A positional parameter reference is used to indicate a value that is supplied externally to an SQL statement. Parameters are used in SQL function definitions and in prepared queries. Some client libraries also support specifying data values separately from the SQL command string, in which case parameters are used to refer to the out-of-line data values. The form of a parameter reference is:

```
$number
```

For example, consider the definition of a function, `dept`, as:

```
CREATE FUNCTION dept(text) RETURNS dept
    AS $$ SELECT * FROM dept WHERE name = $1 $$
    LANGUAGE SQL;
```

Here the `$1` references the value of the first function argument whenever the function is invoked.

4.2.3. Subscripts

If an expression yields a value of an array type, then a specific element of the array value can be extracted by writing

```
expression[subscript]
```

or multiple adjacent elements (an "array slice") can be extracted by writing

```
expression[lower_subscript:upper_subscript]
```

(Here, the brackets `[ ]` are meant to appear literally.) Each *`subscript`* is itself an expression, which must yield an integer value.

In general the array *`expression`* must be parenthesized, but the parentheses can be omitted when the expression to be subscripted is just a column reference or positional parameter. Also, multiple subscripts can be concatenated when the original array is multidimensional. For example:

```
mytable.arraycolumn[4]
mytable.two_d_column[17][34]
$1[10:42]
(arrayfunction(a,b))[42]
```

The parentheses in the last example are required. See Section 8.15 for more about arrays.

4.2.4. Field Selection

If an expression yields a value of a composite type (row type), then a specific field of the row can be extracted by writing

```
expression.fieldname
```

In general the row *`expression`* must be parenthesized, but the parentheses can be omitted when the expression to be selected from is just a table reference or positional parameter. For example:

```
mytable.mycolumn
$1.somecolumn
(rowfunction(a,b)).col3
```

(Thus, a qualified column reference is actually just a special case of the field selection syntax.) An important special case is extracting a field from a table column that is of a composite type:

```
(compositecol).somefield
(mytable.compositecol).somefield
```

The parentheses are required here to show that `compositecol` is a column name not a table name, or that `mytable` is a table name not a schema name in the second case.

In a select list (see Section 7.3), you can ask for all fields of a composite value by writing `.*`:

```
(compositecol).*
```

4.2.5. Operator Invocations

There are three possible syntaxes for an operator invocation:

expression operator expression (binary infix operator)
operator expression (unary prefix operator)
expression operator (unary postfix operator)

where the *operator* token follows the syntax rules of Section 4.1.3, or is one of the key words `AND`, `OR`, and `NOT`, or is a qualified operator name in the form:

```
OPERATOR(schema.operatorname)
```

Which particular operators exist and whether they are unary or binary depends on what operators have been defined by the system or the user. Chapter 9 describes the built-in operators.

4.2.6. Function Calls

The syntax for a function call is the name of a function (possibly qualified with a schema name), followed by its argument list enclosed in parentheses:

```
function_name ([expression [, expression ... ]] )
```

For example, the following computes the square root of 2:

```
sqrt(2)
```

The list of built-in functions is in Chapter 9. Other functions can be added by the user.

The arguments can optionally have names attached. See Section 4.3 for details.

> **Note:** A function that takes a single argument of composite type can optionally be called using field-selection syntax, and conversely field selection can be written in functional style. That is, the notations `col(table)` and `table.col` are interchangeable. This behavior is not SQL-standard but is provided in PostgreSQL because it allows use of functions to emulate “computed fields”. For more information see Section 35.4.3.

4.2.7. Aggregate Expressions

An *aggregate expression* represents the application of an aggregate function across the rows selected by a query. An aggregate function reduces multiple inputs to a single output value, such as the sum or average of the inputs. The syntax of an aggregate expression is one of the following:

```
aggregate_name (expression [ , ... ] [ order_by_clause ] ) [ FILTER ( WHERE filter_clause ) ]
aggregate_name (ALL expression [ , ... ] [ order_by_clause ] ) [ FILTER ( WHERE filter_clause
aggregate_name (DISTINCT expression [ , ... ] [ order_by_clause ] ) [ FILTER ( WHERE filter_c
aggregate_name ( * ) [ FILTER ( WHERE filter_clause ) ]
aggregate_name ( [ expression [ , ... ] ] ) WITHIN GROUP ( order_by_clause ) [ FILTER ( WHER
```

where *aggregate_name* is a previously defined aggregate (possibly qualified with a schema name) and *expression* is any value expression that does not itself contain an aggregate expression or a window function call. The optional *order_by_clause* and *filter_clause* are described below.

The first form of aggregate expression invokes the aggregate once for each input row. The second form is the same as the first, since `ALL` is the default. The third form invokes the aggregate once for each distinct value of the expression (or distinct set of values, for multiple expressions) found in the input rows. The fourth form invokes the aggregate once for each input row; since no particular input value is specified, it is generally only useful for the `count(*)` aggregate function. The last form is used with *ordered-set* aggregate functions, which are described below.

Most aggregate functions ignore null inputs, so that rows in which one or more of the expression(s) yield null are discarded. This can be assumed to be true, unless otherwise specified, for all built-in aggregates.

For example, `count(*)` yields the total number of input rows; `count(f1)` yields the number of input rows in which `f1` is non-null, since `count` ignores nulls; and `count(distinct f1)` yields the number of distinct non-null values of `f1`.

Ordinarily, the input rows are fed to the aggregate function in an unspecified order. In many cases this does not matter; for example, `min` produces the same result no matter what order it receives the inputs in. However, some aggregate functions (such as `array_agg` and `string_agg`) produce results that depend on the ordering of the input rows. When using such an aggregate, the optional *order_by_clause* can be used to specify the desired ordering. The *order_by_clause* has the same syntax as for a query-level `ORDER BY` clause, as described in Section 7.5, except that its expressions are always just expressions and cannot be output-column names or numbers. For example:

```
SELECT array_agg(a ORDER BY b DESC) FROM table;
```

When dealing with multiple-argument aggregate functions, note that the `ORDER BY` clause goes after all the aggregate arguments. For example, write this:

```
SELECT string_agg(a, ',' ORDER BY a) FROM table;
```

not this:

```
SELECT string_agg(a ORDER BY a, ',') FROM table;  -- incorrect
```

The latter is syntactically valid, but it represents a call of a single-argument aggregate function with two `ORDER BY` keys (the second one being rather useless since it's a constant).

If `DISTINCT` is specified in addition to an *order_by_clause*, then all the `ORDER BY` expressions must match regular arguments of the aggregate; that is, you cannot sort on an expression that is not included in the `DISTINCT` list.

Note: The ability to specify both DISTINCT and ORDER BY in an aggregate function is a PostgreSQL extension.

Placing ORDER BY within the aggregate's regular argument list, as described so far, is used when ordering the input rows for a "normal" aggregate for which ordering is optional. There is a subclass of aggregate functions called *ordered-set aggregates* for which an *order_by_clause* is *required*, usually because the aggregate's computation is only sensible in terms of a specific ordering of its input rows. Typical examples of ordered-set aggregates include rank and percentile calculations. For an ordered-set aggregate, the *order_by_clause* is written inside WITHIN GROUP (...), as shown in the final syntax alternative above. The expressions in the *order_by_clause* are evaluated once per input row just like normal aggregate arguments, sorted as per the *order_by_clause*'s requirements, and fed to the aggregate function as input arguments. (This is unlike the case for a non-WITHIN GROUP *order_by_clause*, which is not treated as argument(s) to the aggregate function.) The argument expressions preceding WITHIN GROUP, if any, are called *direct arguments* to distinguish them from the *aggregated arguments* listed in the *order_by_clause*. Unlike normal aggregate arguments, direct arguments are evaluated only once per aggregate call, not once per input row. This means that they can contain variables only if those variables are grouped by GROUP BY; this restriction is the same as if the direct arguments were not inside an aggregate expression at all. Direct arguments are typically used for things like percentile fractions, which only make sense as a single value per aggregation calculation. The direct argument list can be empty; in this case, write just () not (*). (PostgreSQL will actually accept either spelling, but only the first way conforms to the SQL standard.) An example of an ordered-set aggregate call is:

```
SELECT percentile_disc(0.5) WITHIN GROUP (ORDER BY income) FROM households;
 percentile_disc
-----------------
           50489
```

which obtains the 50th percentile, or median, value of the income column from table households. Here, 0.5 is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

If FILTER is specified, then only the input rows for which the *filter_clause* evaluates to true are fed to the aggregate function; other rows are discarded. For example:

```
SELECT
    count(*) AS unfiltered,
    count(*) FILTER (WHERE i < 5) AS filtered
FROM generate_series(1,10) AS s(i);
 unfiltered | filtered
------------+----------
         10 |        4
(1 row)
```

The predefined aggregate functions are described in Section 9.20. Other aggregate functions can be added by the user.

An aggregate expression can only appear in the result list or HAVING clause of a SELECT command. It is forbidden in other clauses, such as WHERE, because those clauses are logically evaluated before the results of aggregates are formed.

When an aggregate expression appears in a subquery (see Section 4.2.11 and Section 9.22), the aggregate is normally evaluated over the rows of the subquery. But an exception occurs if the aggregate's

arguments (and *filter_clause* if any) contain only outer-level variables: the aggregate then belongs to the nearest such outer level, and is evaluated over the rows of that query. The aggregate expression as a whole is then an outer reference for the subquery it appears in, and acts as a constant over any one evaluation of that subquery. The restriction about appearing only in the result list or HAVING clause applies with respect to the query level that the aggregate belongs to.

4.2.8. Window Function Calls

A *window function call* represents the application of an aggregate-like function over some portion of the rows selected by a query. Unlike regular aggregate function calls, this is not tied to grouping of the selected rows into a single output row — each row remains separate in the query output. However the window function is able to scan all the rows that would be part of the current row's group according to the grouping specification (PARTITION BY list) of the window function call. The syntax of a window function call is one of the following:

```
function_name ([expression [, expression ... ]]) [ FILTER ( WHERE filter_clause ) ] OVER wind
function_name ([expression [, expression ... ]]) [ FILTER ( WHERE filter_clause ) ] OVER ( wi
function_name ( * ) [ FILTER ( WHERE filter_clause ) ] OVER window_name
function_name ( * ) [ FILTER ( WHERE filter_clause ) ] OVER ( window_definition )
```

where *window_definition* has the syntax

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

and the optional *frame_clause* can be one of

```
[ RANGE | ROWS ] frame_start
[ RANGE | ROWS ] BETWEEN frame_start AND frame_end
```

where *frame_start* and *frame_end* can be one of

```
UNBOUNDED PRECEDING
value PRECEDING
CURRENT ROW
value FOLLOWING
UNBOUNDED FOLLOWING
```

Here, *expression* represents any value expression that does not itself contain window function calls.

window_name is a reference to a named window specification defined in the query's WINDOW clause. Alternatively, a full *window_definition* can be given within parentheses, using the same syntax as for defining a named window in the WINDOW clause; see the SELECT reference page for details. It's worth pointing out that OVER wname is not exactly equivalent to OVER (wname); the latter implies copying and modifying the window definition, and will be rejected if the referenced window specification includes a frame clause.

The PARTITION BY option groups the rows of the query into *partitions*, which are processed separately by the window function. PARTITION BY works similarly to a query-level GROUP BY clause, except that its expressions are always just expressions and cannot be output-column names or numbers. Without PARTITION BY, all rows produced by the query are treated as a single partition. The ORDER BY option determines the order in which the rows of a partition are processed by the window

function. It works similarly to a query-level ORDER BY clause, but likewise cannot use output-column names or numbers. Without ORDER BY, rows are processed in an unspecified order.

The *frame_clause* specifies the set of rows constituting the *window frame*, which is a subset of the current partition, for those window functions that act on the frame instead of the whole partition. The frame can be specified in either RANGE or ROWS mode; in either case, it runs from the *frame_start* to the *frame_end*. If *frame_end* is omitted, it defaults to CURRENT ROW.

A *frame_start* of UNBOUNDED PRECEDING means that the frame starts with the first row of the partition, and similarly a *frame_end* of UNBOUNDED FOLLOWING means that the frame ends with the last row of the partition.

In RANGE mode, a *frame_start* of CURRENT ROW means the frame starts with the current row's first *peer* row (a row that ORDER BY considers equivalent to the current row), while a *frame_end* of CURRENT ROW means the frame ends with the last equivalent ORDER BY peer. In ROWS mode, CURRENT ROW simply means the current row.

The *value* PRECEDING and *value* FOLLOWING cases are currently only allowed in ROWS mode. They indicate that the frame starts or ends the specified number of rows before or after the current row. *value* must be an integer expression not containing any variables, aggregate functions, or window functions. The value must not be null or negative; but it can be zero, which just selects the current row.

The default framing option is RANGE UNBOUNDED PRECEDING, which is the same as RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW. With ORDER BY, this sets the frame to be all rows from the partition start up through the current row's last ORDER BY peer. Without ORDER BY, all rows of the partition are included in the window frame, since all rows become peers of the current row.

Restrictions are that *frame_start* cannot be UNBOUNDED FOLLOWING, *frame_end* cannot be UNBOUNDED PRECEDING, and the *frame_end* choice cannot appear earlier in the above list than the *frame_start* choice — for example RANGE BETWEEN CURRENT ROW AND *value* PRECEDING is not allowed.

If FILTER is specified, then only the input rows for which the *filter_clause* evaluates to true are fed to the window function; other rows are discarded. Only window functions that are aggregates accept a FILTER clause.

The built-in window functions are described in Table 9-53. Other window functions can be added by the user. Also, any built-in or user-defined normal aggregate function can be used as a window function. Ordered-set aggregates presently cannot be used as window functions, however.

The syntaxes using * are used for calling parameter-less aggregate functions as window functions, for example count(*) OVER (PARTITION BY x ORDER BY y). The asterisk (*) is customarily not used for non-aggregate window functions. Aggregate window functions, unlike normal aggregate functions, do not allow DISTINCT or ORDER BY to be used within the function argument list.

Window function calls are permitted only in the SELECT list and the ORDER BY clause of the query.

More information about window functions can be found in Section 3.5, Section 9.21, and Section 7.2.4.

4.2.9. Type Casts

A type cast specifies a conversion from one data type to another. PostgreSQL accepts two equivalent syntaxes for type casts:

```
CAST ( expression AS type )
```

```
expression::type
```

The CAST syntax conforms to SQL; the syntax with :: is historical PostgreSQL usage.

When a cast is applied to a value expression of a known type, it represents a run-time type conversion. The cast will succeed only if a suitable type conversion operation has been defined. Notice that this is subtly different from the use of casts with constants, as shown in Section 4.1.2.7. A cast applied to an unadorned string literal represents the initial assignment of a type to a literal constant value, and so it will succeed for any type (if the contents of the string literal are acceptable input syntax for the data type).

An explicit type cast can usually be omitted if there is no ambiguity as to the type that a value expression must produce (for example, when it is assigned to a table column); the system will automatically apply a type cast in such cases. However, automatic casting is only done for casts that are marked "OK to apply implicitly" in the system catalogs. Other casts must be invoked with explicit casting syntax. This restriction is intended to prevent surprising conversions from being applied silently.

It is also possible to specify a type cast using a function-like syntax:

```
typename ( expression )
```

However, this only works for types whose names are also valid as function names. For example, double precision cannot be used this way, but the equivalent float8 can. Also, the names interval, time, and timestamp can only be used in this fashion if they are double-quoted, because of syntactic conflicts. Therefore, the use of the function-like cast syntax leads to inconsistencies and should probably be avoided.

> **Note:** The function-like syntax is in fact just a function call. When one of the two standard cast syntaxes is used to do a run-time conversion, it will internally invoke a registered function to perform the conversion. By convention, these conversion functions have the same name as their output type, and thus the "function-like syntax" is nothing more than a direct invocation of the underlying conversion function. Obviously, this is not something that a portable application should rely on. For further details see CREATE CAST.

4.2.10. Collation Expressions

The COLLATE clause overrides the collation of an expression. It is appended to the expression it applies to:

```
expr COLLATE collation
```

where *collation* is a possibly schema-qualified identifier. The COLLATE clause binds tighter than operators; parentheses can be used when necessary.

If no collation is explicitly specified, the database system either derives a collation from the columns involved in the expression, or it defaults to the default collation of the database if no column is involved in the expression.

The two common uses of the COLLATE clause are overriding the sort order in an ORDER BY clause, for example:

```
SELECT a, b, c FROM tbl WHERE ... ORDER BY a COLLATE "C";
```

and overriding the collation of a function or operator call that has locale-sensitive results, for example:

```
SELECT * FROM tbl WHERE a > 'foo' COLLATE "C";
```

Note that in the latter case the COLLATE clause is attached to an input argument of the operator we wish to affect. It doesn't matter which argument of the operator or function call the COLLATE clause is attached to, because the collation that is applied by the operator or function is derived by considering all arguments, and an explicit COLLATE clause will override the collations of all other arguments. (Attaching non-matching COLLATE clauses to more than one argument, however, is an error. For more details see Section 22.2.) Thus, this gives the same result as the previous example:

```
SELECT * FROM tbl WHERE a COLLATE "C" > 'foo';
```

But this is an error:

```
SELECT * FROM tbl WHERE (a > 'foo') COLLATE "C";
```

because it attempts to apply a collation to the result of the > operator, which is of the non-collatable data type boolean.

4.2.11. Scalar Subqueries

A scalar subquery is an ordinary SELECT query in parentheses that returns exactly one row with one column. (See Chapter 7 for information about writing queries.) The SELECT query is executed and the single returned value is used in the surrounding value expression. It is an error to use a query that returns more than one row or more than one column as a scalar subquery. (But if, during a particular execution, the subquery returns no rows, there is no error; the scalar result is taken to be null.) The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery. See also Section 9.22 for other expressions involving subqueries.

For example, the following finds the largest city population in each state:

```
SELECT name, (SELECT max(pop) FROM cities WHERE cities.state = states.name)
    FROM states;
```

4.2.12. Array Constructors

An array constructor is an expression that builds an array value using values for its member elements. A simple array constructor consists of the key word ARRAY, a left square bracket [, a list of expressions (separated by commas) for the array element values, and finally a right square bracket]. For example:

```
SELECT ARRAY[1,2,3+4];
  array
---------
 {1,2,7}
(1 row)
```

By default, the array element type is the common type of the member expressions, determined using the same rules as for UNION or CASE constructs (see Section 10.5). You can override this by explicitly casting the array constructor to the desired type, for example:

```
SELECT ARRAY[1,2,22.7]::integer[];
  array
----------
```

```
 {1,2,23}
(1 row)
```

This has the same effect as casting each expression to the array element type individually. For more on casting, see Section 4.2.9.

Multidimensional array values can be built by nesting array constructors. In the inner constructors, the key word ARRAY can be omitted. For example, these produce the same result:

```
SELECT ARRAY[ARRAY[1,2], ARRAY[3,4]];
     array
---------------
 {{1,2},{3,4}}
(1 row)

SELECT ARRAY[[1,2],[3,4]];
     array
---------------
 {{1,2},{3,4}}
(1 row)
```

Since multidimensional arrays must be rectangular, inner constructors at the same level must produce sub-arrays of identical dimensions. Any cast applied to the outer ARRAY constructor propagates automatically to all the inner constructors.

Multidimensional array constructor elements can be anything yielding an array of the proper kind, not only a sub-ARRAY construct. For example:

```
CREATE TABLE arr(f1 int[], f2 int[]);

INSERT INTO arr VALUES (ARRAY[[1,2],[3,4]], ARRAY[[5,6],[7,8]]);

SELECT ARRAY[f1, f2, '{{9,10},{11,12}}'::int[]] FROM arr;
                     array
------------------------------------------------
 {{{1,2},{3,4}},{{5,6},{7,8}},{{9,10},{11,12}}}
(1 row)
```

You can construct an empty array, but since it's impossible to have an array with no type, you must explicitly cast your empty array to the desired type. For example:

```
SELECT ARRAY[]::integer[];
 array
-------
 {}
(1 row)
```

It is also possible to construct an array from the results of a subquery. In this form, the array constructor is written with the key word ARRAY followed by a parenthesized (not bracketed) subquery. For example:

```
SELECT ARRAY(SELECT oid FROM pg_proc WHERE proname LIKE 'bytea%');
                                array
----------------------------------------------------------------------
 {2011,1954,1948,1952,1951,1244,1950,2005,1949,1953,2006,31,2412,2413}
```

```
(1 row)
```

The subquery must return a single column. The resulting one-dimensional array will have an element for each row in the subquery result, with an element type matching that of the subquery's output column.

The subscripts of an array value built with ARRAY always begin with one. For more information about arrays, see Section 8.15.

4.2.13. Row Constructors

A row constructor is an expression that builds a row value (also called a composite value) using values for its member fields. A row constructor consists of the key word ROW, a left parenthesis, zero or more expressions (separated by commas) for the row field values, and finally a right parenthesis. For example:

```
SELECT ROW(1,2.5,'this is a test');
```

The key word ROW is optional when there is more than one expression in the list.

A row constructor can include the syntax *rowvalue*.*, which will be expanded to a list of the elements of the row value, just as occurs when the .* syntax is used at the top level of a SELECT list. For example, if table t has columns f1 and f2, these are the same:

```
SELECT ROW(t.*, 42) FROM t;
SELECT ROW(t.f1, t.f2, 42) FROM t;
```

> **Note:** Before PostgreSQL 8.2, the .* syntax was not expanded, so that writing ROW(t.*, 42) created a two-field row whose first field was another row value. The new behavior is usually more useful. If you need the old behavior of nested row values, write the inner row value without .*, for instance ROW(t, 42).

By default, the value created by a ROW expression is of an anonymous record type. If necessary, it can be cast to a named composite type — either the row type of a table, or a composite type created with CREATE TYPE AS. An explicit cast might be needed to avoid ambiguity. For example:

```
CREATE TABLE mytable(f1 int, f2 float, f3 text);

CREATE FUNCTION getf1(mytable) RETURNS int AS 'SELECT $1.f1' LANGUAGE SQL;

-- No cast needed since only one getf1() exists
SELECT getf1(ROW(1,2.5,'this is a test'));
 getf1
-------
     1
(1 row)

CREATE TYPE myrowtype AS (f1 int, f2 text, f3 numeric);

CREATE FUNCTION getf1(myrowtype) RETURNS int AS 'SELECT $1.f1' LANGUAGE SQL;

-- Now we need a cast to indicate which function to call:
```

```
SELECT getf1(ROW(1,2.5,'this is a test'));
ERROR:  function getf1(record) is not unique

SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
 getf1
-------
     1
(1 row)

SELECT getf1(CAST(ROW(11,'this is a test',2.5) AS myrowtype));
 getf1
-------
    11
(1 row)
```

Row constructors can be used to build composite values to be stored in a composite-type table column, or to be passed to a function that accepts a composite parameter. Also, it is possible to compare two row values or test a row with `IS NULL` or `IS NOT NULL`, for example:

```
SELECT ROW(1,2.5,'this is a test') = ROW(1, 3, 'not the same');

SELECT ROW(table.*) IS NULL FROM table;  -- detect all-null rows
```

For more detail see Section 9.23. Row constructors can also be used in connection with subqueries, as discussed in Section 9.22.

4.2.14. Expression Evaluation Rules

The order of evaluation of subexpressions is not defined. In particular, the inputs of an operator or function are not necessarily evaluated left-to-right or in any other fixed order.

Furthermore, if the result of an expression can be determined by evaluating only some parts of it, then other subexpressions might not be evaluated at all. For instance, if one wrote:

```
SELECT true OR somefunc();
```

then `somefunc()` would (probably) not be called at all. The same would be the case if one wrote:

```
SELECT somefunc() OR true;
```

Note that this is not the same as the left-to-right "short-circuiting" of Boolean operators that is found in some programming languages.

As a consequence, it is unwise to use functions with side effects as part of complex expressions. It is particularly dangerous to rely on side effects or evaluation order in `WHERE` and `HAVING` clauses, since those clauses are extensively reprocessed as part of developing an execution plan. Boolean expressions (`AND`/`OR`/`NOT` combinations) in those clauses can be reorganized in any manner allowed by the laws of Boolean algebra.

When it is essential to force evaluation order, a `CASE` construct (see Section 9.17) can be used. For example, this is an untrustworthy way of trying to avoid division by zero in a `WHERE` clause:

```
SELECT ... WHERE x > 0 AND y/x > 1.5;
```

But this is safe:

```
SELECT ... WHERE CASE WHEN x > 0 THEN y/x > 1.5 ELSE false END;
```

A CASE construct used in this fashion will defeat optimization attempts, so it should only be done when necessary. (In this particular example, it would be better to sidestep the problem by writing y > 1.5*x instead.)

CASE is not a cure-all for such issues, however. One limitation of the technique illustrated above is that it does not prevent early evaluation of constant subexpressions. As described in Section 35.6, functions and operators marked IMMUTABLE can be evaluated when the query is planned rather than when it is executed. Thus for example

```
SELECT CASE WHEN x > 0 THEN x ELSE 1/0 END FROM tab;
```

is likely to result in a division-by-zero failure due to the planner trying to simplify the constant subexpression, even if every row in the table has x > 0 so that the ELSE arm would never be entered at run time.

While that particular example might seem silly, related cases that don't obviously involve constants can occur in queries executed within functions, since the values of function arguments and local variables can be inserted into queries as constants for planning purposes. Within PL/pgSQL functions, for example, using an IF-THEN-ELSE statement to protect a risky computation is much safer than just nesting it in a CASE expression.

Another limitation of the same kind is that a CASE cannot prevent evaluation of an aggregate expression contained within it, because aggregate expressions are computed before other expressions in a SELECT list or HAVING clause are considered. For example, the following query can cause a division-by-zero error despite seemingly having protected against it:

```
SELECT CASE WHEN min(employees) > 0
            THEN avg(expenses / employees)
       END
    FROM departments;
```

The min() and avg() aggregates are computed concurrently over all the input rows, so if any row has employees equal to zero, the division-by-zero error will occur before there is any opportunity to test the result of min(). Instead, use a WHERE or FILTER clause to prevent problematic input rows from reaching an aggregate function in the first place.

4.3. Calling Functions

PostgreSQL allows functions that have named parameters to be called using either *positional* or *named* notation. Named notation is especially useful for functions that have a large number of parameters, since it makes the associations between parameters and actual arguments more explicit and reliable. In positional notation, a function call is written with its argument values in the same order as they are defined in the function declaration. In named notation, the arguments are matched to the function parameters by name and can be written in any order.

In either notation, parameters that have default values given in the function declaration need not be written in the call at all. But this is particularly useful in named notation, since any combination of parameters can be omitted; while in positional notation parameters can only be omitted from right to left.

PostgreSQL also supports *mixed* notation, which combines positional and named notation. In this case, positional parameters are written first and named parameters appear after them.

The following examples will illustrate the usage of all three notations, using the following function definition:

```
CREATE FUNCTION concat_lower_or_upper(a text, b text, uppercase boolean DEFAULT false)
RETURNS text
AS
$$
 SELECT CASE
        WHEN $3 THEN UPPER($1 || ' ' || $2)
        ELSE LOWER($1 || ' ' || $2)
        END;
$$
LANGUAGE SQL IMMUTABLE STRICT;
```

Function `concat_lower_or_upper` has two mandatory parameters, `a` and `b`. Additionally there is one optional parameter `uppercase` which defaults to `false`. The `a` and `b` inputs will be concatenated, and forced to either upper or lower case depending on the `uppercase` parameter. The remaining details of this function definition are not important here (see Chapter 35 for more information).

4.3.1. Using Positional Notation

Positional notation is the traditional mechanism for passing arguments to functions in PostgreSQL. An example is:

```
SELECT concat_lower_or_upper('Hello', 'World', true);
 concat_lower_or_upper
-----------------------
 HELLO WORLD
(1 row)
```

All arguments are specified in order. The result is upper case since `uppercase` is specified as `true`. Another example is:

```
SELECT concat_lower_or_upper('Hello', 'World');
 concat_lower_or_upper
-----------------------
 hello world
(1 row)
```

Here, the `uppercase` parameter is omitted, so it receives its default value of `false`, resulting in lower case output. In positional notation, arguments can be omitted from right to left so long as they have defaults.

4.3.2. Using Named Notation

In named notation, each argument's name is specified using `:=` to separate it from the argument expression. For example:

```
SELECT concat_lower_or_upper(a := 'Hello', b := 'World');
 concat_lower_or_upper
-----------------------
 hello world
(1 row)
```

Again, the argument `uppercase` was omitted so it is set to `false` implicitly. One advantage of using named notation is that the arguments may be specified in any order, for example:

```
SELECT concat_lower_or_upper(a := 'Hello', b := 'World', uppercase := true);
 concat_lower_or_upper
-----------------------
 HELLO WORLD
(1 row)

SELECT concat_lower_or_upper(a := 'Hello', uppercase := true, b := 'World');
 concat_lower_or_upper
-----------------------
 HELLO WORLD
(1 row)
```

4.3.3. Using Mixed Notation

The mixed notation combines positional and named notation. However, as already mentioned, named arguments cannot precede positional arguments. For example:

```
SELECT concat_lower_or_upper('Hello', 'World', uppercase := true);
 concat_lower_or_upper
-----------------------
 HELLO WORLD
(1 row)
```

In the above query, the arguments `a` and `b` are specified positionally, while `uppercase` is specified by name. In this example, that adds little except documentation. With a more complex function having numerous parameters that have default values, named or mixed notation can save a great deal of writing and reduce chances for error.

> **Note:** Named and mixed call notations currently cannot be used when calling an aggregate function (but they do work when an aggregate function is used as a window function).

Chapter 5. Data Definition

This chapter covers how one creates the database structures that will hold one's data. In a relational database, the raw data is stored in tables, so the majority of this chapter is devoted to explaining how tables are created and modified and what features are available to control what data is stored in the tables. Subsequently, we discuss how tables can be organized into schemas, and how privileges can be assigned to tables. Finally, we will briefly look at other features that affect the data storage, such as inheritance, views, functions, and triggers.

5.1. Table Basics

A table in a relational database is much like a table on paper: It consists of rows and columns. The number and order of the columns is fixed, and each column has a name. The number of rows is variable — it reflects how much data is stored at a given moment. SQL does not make any guarantees about the order of the rows in a table. When a table is read, the rows will appear in an unspecified order, unless sorting is explicitly requested. This is covered in Chapter 7. Furthermore, SQL does not assign unique identifiers to rows, so it is possible to have several completely identical rows in a table. This is a consequence of the mathematical model that underlies SQL but is usually not desirable. Later in this chapter we will see how to deal with this issue.

Each column has a data type. The data type constrains the set of possible values that can be assigned to a column and assigns semantics to the data stored in the column so that it can be used for computations. For instance, a column declared to be of a numerical type will not accept arbitrary text strings, and the data stored in such a column can be used for mathematical computations. By contrast, a column declared to be of a character string type will accept almost any kind of data but it does not lend itself to mathematical calculations, although other operations such as string concatenation are available.

PostgreSQL includes a sizable set of built-in data types that fit many applications. Users can also define their own data types. Most built-in data types have obvious names and semantics, so we defer a detailed explanation to Chapter 8. Some of the frequently used data types are `integer` for whole numbers, `numeric` for possibly fractional numbers, `text` for character strings, `date` for dates, `time` for time-of-day values, and `timestamp` for values containing both date and time.

To create a table, you use the aptly named CREATE TABLE command. In this command you specify at least a name for the new table, the names of the columns and the data type of each column. For example:

```
CREATE TABLE my_first_table (
    first_column text,
    second_column integer
);
```

This creates a table named `my_first_table` with two columns. The first column is named `first_column` and has a data type of `text`; the second column has the name `second_column` and the type `integer`. The table and column names follow the identifier syntax explained in Section 4.1.1. The type names are usually also identifiers, but there are some exceptions. Note that the column list is comma-separated and surrounded by parentheses.

Of course, the previous example was heavily contrived. Normally, you would give names to your tables and columns that convey what kind of data they store. So let's look at a more realistic example:

```
CREATE TABLE products (
```

```
    product_no integer,
    name text,
    price numeric
);
```

(The `numeric` type can store fractional components, as would be typical of monetary amounts.)

> **Tip:** When you create many interrelated tables it is wise to choose a consistent naming pattern for the tables and columns. For instance, there is a choice of using singular or plural nouns for table names, both of which are favored by some theorist or other.

There is a limit on how many columns a table can contain. Depending on the column types, it is between 250 and 1600. However, defining a table with anywhere near this many columns is highly unusual and often a questionable design.

If you no longer need a table, you can remove it using the DROP TABLE command. For example:

```
DROP TABLE my_first_table;
DROP TABLE products;
```

Attempting to drop a table that does not exist is an error. Nevertheless, it is common in SQL script files to unconditionally try to drop each table before creating it, ignoring any error messages, so that the script works whether or not the table exists. (If you like, you can use the `DROP TABLE IF EXISTS` variant to avoid the error messages, but this is not standard SQL.)

If you need to modify a table that already exists, see Section 5.5 later in this chapter.

With the tools discussed so far you can create fully functional tables. The remainder of this chapter is concerned with adding features to the table definition to ensure data integrity, security, or convenience. If you are eager to fill your tables with data now you can skip ahead to Chapter 6 and read the rest of this chapter later.

5.2. Default Values

A column can be assigned a default value. When a new row is created and no values are specified for some of the columns, those columns will be filled with their respective default values. A data manipulation command can also request explicitly that a column be set to its default value, without having to know what that value is. (Details about data manipulation commands are in Chapter 6.)

If no default value is declared explicitly, the default value is the null value. This usually makes sense because a null value can be considered to represent unknown data.

In a table definition, default values are listed after the column data type. For example:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric DEFAULT 9.99
);
```

The default value can be an expression, which will be evaluated whenever the default value is inserted (*not* when the table is created). A common example is for a `timestamp` column to have a default of

CURRENT_TIMESTAMP, so that it gets set to the time of row insertion. Another common example is generating a "serial number" for each row. In PostgreSQL this is typically done by something like:

```
CREATE TABLE products (
    product_no integer DEFAULT nextval('products_product_no_seq'),
    ...
);
```

where the nextval() function supplies successive values from a *sequence object* (see Section 9.16). This arrangement is sufficiently common that there's a special shorthand for it:

```
CREATE TABLE products (
    product_no SERIAL,
    ...
);
```

The SERIAL shorthand is discussed further in Section 8.1.4.

5.3. Constraints

Data types are a way to limit the kind of data that can be stored in a table. For many applications, however, the constraint they provide is too coarse. For example, a column containing a product price should probably only accept positive values. But there is no standard data type that accepts only positive numbers. Another issue is that you might want to constrain column data with respect to other columns or rows. For example, in a table containing product information, there should be only one row for each product number.

To that end, SQL allows you to define constraints on columns and tables. Constraints give you as much control over the data in your tables as you wish. If a user attempts to store data in a column that would violate a constraint, an error is raised. This applies even if the value came from the default value definition.

5.3.1. Check Constraints

A check constraint is the most generic constraint type. It allows you to specify that the value in a certain column must satisfy a Boolean (truth-value) expression. For instance, to require positive product prices, you could use:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric CHECK (price > 0)
);
```

As you see, the constraint definition comes after the data type, just like default value definitions. Default values and constraints can be listed in any order. A check constraint consists of the key word CHECK followed by an expression in parentheses. The check constraint expression should involve the column thus constrained, otherwise the constraint would not make too much sense.

You can also give the constraint a separate name. This clarifies error messages and allows you to refer to the constraint when you need to change it. The syntax is:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric CONSTRAINT positive_price CHECK (price > 0)
);
```

So, to specify a named constraint, use the key word `CONSTRAINT` followed by an identifier followed by the constraint definition. (If you don't specify a constraint name in this way, the system chooses a name for you.)

A check constraint can also refer to several columns. Say you store a regular price and a discounted price, and you want to ensure that the discounted price is lower than the regular price:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric CHECK (price > 0),
    discounted_price numeric CHECK (discounted_price > 0),
    CHECK (price > discounted_price)
);
```

The first two constraints should look familiar. The third one uses a new syntax. It is not attached to a particular column, instead it appears as a separate item in the comma-separated column list. Column definitions and these constraint definitions can be listed in mixed order.

We say that the first two constraints are column constraints, whereas the third one is a table constraint because it is written separately from any one column definition. Column constraints can also be written as table constraints, while the reverse is not necessarily possible, since a column constraint is supposed to refer to only the column it is attached to. (PostgreSQL doesn't enforce that rule, but you should follow it if you want your table definitions to work with other database systems.) The above example could also be written as:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric,
    CHECK (price > 0),
    discounted_price numeric,
    CHECK (discounted_price > 0),
    CHECK (price > discounted_price)
);
```

or even:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric CHECK (price > 0),
    discounted_price numeric,
    CHECK (discounted_price > 0 AND price > discounted_price)
);
```

It's a matter of taste.

Names can be assigned to table constraints in the same way as column constraints:

```
CREATE TABLE products (
```

```
    product_no integer,
    name text,
    price numeric,
    CHECK (price > 0),
    discounted_price numeric,
    CHECK (discounted_price > 0),
    CONSTRAINT valid_discount CHECK (price > discounted_price)
);
```

It should be noted that a check constraint is satisfied if the check expression evaluates to true or the null value. Since most expressions will evaluate to the null value if any operand is null, they will not prevent null values in the constrained columns. To ensure that a column does not contain null values, the not-null constraint described in the next section can be used.

5.3.2. Not-Null Constraints

A not-null constraint simply specifies that a column must not assume the null value. A syntax example:

```
CREATE TABLE products (
    product_no integer NOT NULL,
    name text NOT NULL,
    price numeric
);
```

A not-null constraint is always written as a column constraint. A not-null constraint is functionally equivalent to creating a check constraint `CHECK (column_name IS NOT NULL)`, but in PostgreSQL creating an explicit not-null constraint is more efficient. The drawback is that you cannot give explicit names to not-null constraints created this way.

Of course, a column can have more than one constraint. Just write the constraints one after another:

```
CREATE TABLE products (
    product_no integer NOT NULL,
    name text NOT NULL,
    price numeric NOT NULL CHECK (price > 0)
);
```

The order doesn't matter. It does not necessarily determine in which order the constraints are checked.

The `NOT NULL` constraint has an inverse: the `NULL` constraint. This does not mean that the column must be null, which would surely be useless. Instead, this simply selects the default behavior that the column might be null. The `NULL` constraint is not present in the SQL standard and should not be used in portable applications. (It was only added to PostgreSQL to be compatible with some other database systems.) Some users, however, like it because it makes it easy to toggle the constraint in a script file. For example, you could start with:

```
CREATE TABLE products (
    product_no integer NULL,
    name text NULL,
    price numeric NULL
);
```

and then insert the `NOT` key word where desired.

Tip: In most database designs the majority of columns should be marked not null.

5.3.3. Unique Constraints

Unique constraints ensure that the data contained in a column or a group of columns is unique with respect to all the rows in the table. The syntax is:

```
CREATE TABLE products (
    product_no integer UNIQUE,
    name text,
    price numeric
);
```

when written as a column constraint, and:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric,
    UNIQUE (product_no)
);
```

when written as a table constraint.

If a unique constraint refers to a group of columns, the columns are listed separated by commas:

```
CREATE TABLE example (
    a integer,
    b integer,
    c integer,
    UNIQUE (a, c)
);
```

This specifies that the combination of values in the indicated columns is unique across the whole table, though any one of the columns need not be (and ordinarily isn't) unique.

You can assign your own name for a unique constraint, in the usual way:

```
CREATE TABLE products (
    product_no integer CONSTRAINT must_be_different UNIQUE,
    name text,
    price numeric
);
```

Adding a unique constraint will automatically create a unique btree index on the column or group of columns used in the constraint. A uniqueness constraint on only some rows can be enforced by creating a partial index.

In general, a unique constraint is violated when there is more than one row in the table where the values of all of the columns included in the constraint are equal. However, two null values are not considered equal in this comparison. That means even in the presence of a unique constraint it is possible to store duplicate rows that contain a null value in at least one of the constrained columns.

This behavior conforms to the SQL standard, but we have heard that other SQL databases might not follow this rule. So be careful when developing applications that are intended to be portable.

5.3.4. Primary Keys

Technically, a primary key constraint is simply a combination of a unique constraint and a not-null constraint. So, the following two table definitions accept the same data:

```
CREATE TABLE products (
    product_no integer UNIQUE NOT NULL,
    name text,
    price numeric
);

CREATE TABLE products (
    product_no integer PRIMARY KEY,
    name text,
    price numeric
);
```

Primary keys can also constrain more than one column; the syntax is similar to unique constraints:

```
CREATE TABLE example (
    a integer,
    b integer,
    c integer,
    PRIMARY KEY (a, c)
);
```

A primary key indicates that a column or group of columns can be used as a unique identifier for rows in the table. (This is a direct consequence of the definition of a primary key. Note that a unique constraint does not, by itself, provide a unique identifier because it does not exclude null values.) This is useful both for documentation purposes and for client applications. For example, a GUI application that allows modifying row values probably needs to know the primary key of a table to be able to identify rows uniquely.

Adding a primary key will automatically create a unique btree index on the column or group of columns used in the primary key.

A table can have at most one primary key. (There can be any number of unique and not-null constraints, which are functionally the same thing, but only one can be identified as the primary key.) Relational database theory dictates that every table must have a primary key. This rule is not enforced by PostgreSQL, but it is usually best to follow it.

5.3.5. Foreign Keys

A foreign key constraint specifies that the values in a column (or a group of columns) must match the values appearing in some row of another table. We say this maintains the *referential integrity* between two related tables.

Say you have the product table that we have used several times already:

```
CREATE TABLE products (
    product_no integer PRIMARY KEY,
    name text,
    price numeric
);
```

Let's also assume you have a table storing orders of those products. We want to ensure that the orders table only contains orders of products that actually exist. So we define a foreign key constraint in the orders table that references the products table:

```
CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    product_no integer REFERENCES products (product_no),
    quantity integer
);
```

Now it is impossible to create orders with non-NULL `product_no` entries that do not appear in the products table.

We say that in this situation the orders table is the *referencing* table and the products table is the *referenced* table. Similarly, there are referencing and referenced columns.

You can also shorten the above command to:

```
CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    product_no integer REFERENCES products,
    quantity integer
);
```

because in absence of a column list the primary key of the referenced table is used as the referenced column(s).

A foreign key can also constrain and reference a group of columns. As usual, it then needs to be written in table constraint form. Here is a contrived syntax example:

```
CREATE TABLE t1 (
  a integer PRIMARY KEY,
  b integer,
  c integer,
  FOREIGN KEY (b, c) REFERENCES other_table (c1, c2)
);
```

Of course, the number and type of the constrained columns need to match the number and type of the referenced columns.

You can assign your own name for a foreign key constraint, in the usual way.

A table can have more than one foreign key constraint. This is used to implement many-to-many relationships between tables. Say you have tables about products and orders, but now you want to allow one order to contain possibly many products (which the structure above did not allow). You could use this table structure:

```
CREATE TABLE products (
    product_no integer PRIMARY KEY,
    name text,
    price numeric
);
```

```
CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    shipping_address text,
    ...
);

CREATE TABLE order_items (
    product_no integer REFERENCES products,
    order_id integer REFERENCES orders,
    quantity integer,
    PRIMARY KEY (product_no, order_id)
);
```

Notice that the primary key overlaps with the foreign keys in the last table.

We know that the foreign keys disallow creation of orders that do not relate to any products. But what if a product is removed after an order is created that references it? SQL allows you to handle that as well. Intuitively, we have a few options:

- Disallow deleting a referenced product
- Delete the orders as well
- Something else?

To illustrate this, let's implement the following policy on the many-to-many relationship example above: when someone wants to remove a product that is still referenced by an order (via `order_items`), we disallow it. If someone removes an order, the order items are removed as well:

```
CREATE TABLE products (
    product_no integer PRIMARY KEY,
    name text,
    price numeric
);

CREATE TABLE orders (
    order_id integer PRIMARY KEY,
    shipping_address text,
    ...
);

CREATE TABLE order_items (
    product_no integer REFERENCES products ON DELETE RESTRICT,
    order_id integer REFERENCES orders ON DELETE CASCADE,
    quantity integer,
    PRIMARY KEY (product_no, order_id)
);
```

Restricting and cascading deletes are the two most common options. `RESTRICT` prevents deletion of a referenced row. `NO ACTION` means that if any referencing rows still exist when the constraint is checked, an error is raised; this is the default behavior if you do not specify anything. (The essential difference between these two choices is that `NO ACTION` allows the check to be deferred until later in the transaction, whereas `RESTRICT` does not.) `CASCADE` specifies that when a referenced row is deleted, row(s) referencing it should be automatically deleted as well. There are two other options: `SET NULL` and `SET DEFAULT`. These cause the referencing column(s) in the referencing row(s) to be

set to nulls or their default values, respectively, when the referenced row is deleted. Note that these do not excuse you from observing any constraints. For example, if an action specifies `SET DEFAULT` but the default value would not satisfy the foreign key constraint, the operation will fail.

Analogous to `ON DELETE` there is also `ON UPDATE` which is invoked when a referenced column is changed (updated). The possible actions are the same. In this case, `CASCADE` means that the updated values of the referenced column(s) should be copied into the referencing row(s).

Normally, a referencing row need not satisfy the foreign key constraint if any of its referencing columns are null. If `MATCH FULL` is added to the foreign key declaration, a referencing row escapes satisfying the constraint only if all its referencing columns are null (so a mix of null and non-null values is guaranteed to fail a `MATCH FULL` constraint). If you don't want referencing rows to be able to avoid satisfying the foreign key constraint, declare the referencing column(s) as `NOT NULL`.

A foreign key must reference columns that either are a primary key or form a unique constraint. This means that the referenced columns always have an index (the one underlying the primary key or unique constraint); so checks on whether a referencing row has a match will be efficient. Since a `DELETE` of a row from the referenced table or an `UPDATE` of a referenced column will require a scan of the referencing table for rows matching the old value, it is often a good idea to index the referencing columns too. Because this is not always needed, and there are many choices available on how to index, declaration of a foreign key constraint does not automatically create an index on the referencing columns.

More information about updating and deleting data is in Chapter 6. Also see the description of foreign key constraint syntax in the reference documentation for CREATE TABLE.

5.3.6. Exclusion Constraints

Exclusion constraints ensure that if any two rows are compared on the specified columns or expressions using the specified operators, at least one of these operator comparisons will return false or null. The syntax is:

```
CREATE TABLE circles (
    c circle,
    EXCLUDE USING gist (c WITH &&)
);
```

See also `CREATE TABLE ... CONSTRAINT ... EXCLUDE` for details.

Adding an exclusion constraint will automatically create an index of the type specified in the constraint declaration.

5.4. System Columns

Every table has several *system columns* that are implicitly defined by the system. Therefore, these names cannot be used as names of user-defined columns. (Note that these restrictions are separate from whether the name is a key word or not; quoting a name will not allow you to escape these restrictions.) You do not really need to be concerned about these columns; just know they exist.

`oid`

The object identifier (object ID) of a row. This column is only present if the table was created using `WITH OIDS`, or if the default_with_oids configuration variable was set at the time. This column is of type `oid` (same name as the column); see Section 8.18 for more information about the type.

`tableoid`

The OID of the table containing this row. This column is particularly handy for queries that select from inheritance hierarchies (see Section 5.8), since without it, it's difficult to tell which individual table a row came from. The `tableoid` can be joined against the `oid` column of `pg_class` to obtain the table name.

`xmin`

The identity (transaction ID) of the inserting transaction for this row version. (A row version is an individual state of a row; each update of a row creates a new row version for the same logical row.)

`cmin`

The command identifier (starting at zero) within the inserting transaction.

`xmax`

The identity (transaction ID) of the deleting transaction, or zero for an undeleted row version. It is possible for this column to be nonzero in a visible row version. That usually indicates that the deleting transaction hasn't committed yet, or that an attempted deletion was rolled back.

`cmax`

The command identifier within the deleting transaction, or zero.

`ctid`

The physical location of the row version within its table. Note that although the `ctid` can be used to locate the row version very quickly, a row's `ctid` will change if it is updated or moved by `VACUUM FULL`. Therefore `ctid` is useless as a long-term row identifier. The OID, or even better a user-defined serial number, should be used to identify logical rows.

OIDs are 32-bit quantities and are assigned from a single cluster-wide counter. In a large or long-lived database, it is possible for the counter to wrap around. Hence, it is bad practice to assume that OIDs are unique, unless you take steps to ensure that this is the case. If you need to identify the rows in a table, using a sequence generator is strongly recommended. However, OIDs can be used as well, provided that a few additional precautions are taken:

- A unique constraint should be created on the OID column of each table for which the OID will be used to identify rows. When such a unique constraint (or unique index) exists, the system takes care not to generate an OID matching an already-existing row. (Of course, this is only possible if the table contains fewer than 2^{32} (4 billion) rows, and in practice the table size had better be much less than that, or performance might suffer.)
- OIDs should never be assumed to be unique across tables; use the combination of `tableoid` and row OID if you need a database-wide identifier.
- Of course, the tables in question must be created `WITH OIDS`. As of PostgreSQL 8.1, `WITHOUT OIDS` is the default.

Transaction identifiers are also 32-bit quantities. In a long-lived database it is possible for transaction IDs to wrap around. This is not a fatal problem given appropriate maintenance procedures; see Chapter 23 for details. It is unwise, however, to depend on the uniqueness of transaction IDs over the long term (more than one billion transactions).

Command identifiers are also 32-bit quantities. This creates a hard limit of 2^{32} (4 billion) SQL commands within a single transaction. In practice this limit is not a problem — note that the limit is on the number of SQL commands, not the number of rows processed. Also, only commands that actually modify the database contents will consume a command identifier.

5.5. Modifying Tables

When you create a table and you realize that you made a mistake, or the requirements of the application change, you can drop the table and create it again. But this is not a convenient option if the table is already filled with data, or if the table is referenced by other database objects (for instance a foreign key constraint). Therefore PostgreSQL provides a family of commands to make modifications to existing tables. Note that this is conceptually distinct from altering the data contained in the table: here we are interested in altering the definition, or structure, of the table.

You can:

- Add columns
- Remove columns
- Add constraints
- Remove constraints
- Change default values
- Change column data types
- Rename columns
- Rename tables

All these actions are performed using the ALTER TABLE command, whose reference page contains details beyond those given here.

5.5.1. Adding a Column

To add a column, use a command like:

```
ALTER TABLE products ADD COLUMN description text;
```

The new column is initially filled with whatever default value is given (null if you don't specify a `DEFAULT` clause).

You can also define constraints on the column at the same time, using the usual syntax:

```
ALTER TABLE products ADD COLUMN description text CHECK (description <> '');
```

In fact all the options that can be applied to a column description in `CREATE TABLE` can be used here. Keep in mind however that the default value must satisfy the given constraints, or the `ADD` will fail. Alternatively, you can add constraints later (see below) after you've filled in the new column correctly.

> **Tip:** Adding a column with a default requires updating each row of the table (to store the new column value). However, if no default is specified, PostgreSQL is able to avoid the physical update. So if you intend to fill the column with mostly nondefault values, it's best to add the column with

no default, insert the correct values using `UPDATE`, and then add any desired default as described below.

5.5.2. Removing a Column

To remove a column, use a command like:

```
ALTER TABLE products DROP COLUMN description;
```

Whatever data was in the column disappears. Table constraints involving the column are dropped, too. However, if the column is referenced by a foreign key constraint of another table, PostgreSQL will not silently drop that constraint. You can authorize dropping everything that depends on the column by adding `CASCADE`:

```
ALTER TABLE products DROP COLUMN description CASCADE;
```

See Section 5.12 for a description of the general mechanism behind this.

5.5.3. Adding a Constraint

To add a constraint, the table constraint syntax is used. For example:

```
ALTER TABLE products ADD CHECK (name <> '');
ALTER TABLE products ADD CONSTRAINT some_name UNIQUE (product_no);
ALTER TABLE products ADD FOREIGN KEY (product_group_id) REFERENCES product_groups;
```

To add a not-null constraint, which cannot be written as a table constraint, use this syntax:

```
ALTER TABLE products ALTER COLUMN product_no SET NOT NULL;
```

The constraint will be checked immediately, so the table data must satisfy the constraint before it can be added.

5.5.4. Removing a Constraint

To remove a constraint you need to know its name. If you gave it a name then that's easy. Otherwise the system assigned a generated name, which you need to find out. The psql command `\d` *`tablename`* can be helpful here; other interfaces might also provide a way to inspect table details. Then the command is:

```
ALTER TABLE products DROP CONSTRAINT some_name;
```

(If you are dealing with a generated constraint name like `$2`, don't forget that you'll need to double-quote it to make it a valid identifier.)

As with dropping a column, you need to add `CASCADE` if you want to drop a constraint that something else depends on. An example is that a foreign key constraint depends on a unique or primary key constraint on the referenced column(s).

This works the same for all constraint types except not-null constraints. To drop a not null constraint use:

```
ALTER TABLE products ALTER COLUMN product_no DROP NOT NULL;
```

(Recall that not-null constraints do not have names.)

5.5.5. Changing a Column's Default Value

To set a new default for a column, use a command like:

```
ALTER TABLE products ALTER COLUMN price SET DEFAULT 7.77;
```

Note that this doesn't affect any existing rows in the table, it just changes the default for future `INSERT` commands.

To remove any default value, use:

```
ALTER TABLE products ALTER COLUMN price DROP DEFAULT;
```

This is effectively the same as setting the default to null. As a consequence, it is not an error to drop a default where one hadn't been defined, because the default is implicitly the null value.

5.5.6. Changing a Column's Data Type

To convert a column to a different data type, use a command like:

```
ALTER TABLE products ALTER COLUMN price TYPE numeric(10,2);
```

This will succeed only if each existing entry in the column can be converted to the new type by an implicit cast. If a more complex conversion is needed, you can add a `USING` clause that specifies how to compute the new values from the old.

PostgreSQL will attempt to convert the column's default value (if any) to the new type, as well as any constraints that involve the column. But these conversions might fail, or might produce surprising results. It's often best to drop any constraints on the column before altering its type, and then add back suitably modified constraints afterwards.

5.5.7. Renaming a Column

To rename a column:

```
ALTER TABLE products RENAME COLUMN product_no TO product_number;
```

5.5.8. Renaming a Table

To rename a table:

```
ALTER TABLE products RENAME TO items;
```

5.6. Privileges

When an object is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, *privileges* must be granted.

There are different kinds of privileges: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, `REFERENCES`, `TRIGGER`, `CREATE`, `CONNECT`, `TEMPORARY`, `EXECUTE`, and `USAGE`. The privileges applicable to a particular object vary depending on the object's type (table, function, etc). For complete information on the different types of privileges supported by PostgreSQL, refer to the GRANT reference page. The following sections and chapters will also show you how those privileges are used.

The right to modify or destroy an object is always the privilege of the owner only.

An object can be assigned to a new owner with an `ALTER` command of the appropriate kind for the object, e.g. ALTER TABLE. Superusers can always do this; ordinary roles can only do it if they are both the current owner of the object (or a member of the owning role) and a member of the new owning role.

To assign privileges, the `GRANT` command is used. For example, if `joe` is an existing user, and `accounts` is an existing table, the privilege to update the table can be granted with:

```
GRANT UPDATE ON accounts TO joe;
```

Writing `ALL` in place of a specific privilege grants all privileges that are relevant for the object type.

The special "user" name `PUBLIC` can be used to grant a privilege to every user on the system. Also, "group" roles can be set up to help manage privileges when there are many users of a database — for details see Chapter 20.

To revoke a privilege, use the fittingly named `REVOKE` command:

```
REVOKE ALL ON accounts FROM PUBLIC;
```

The special privileges of the object owner (i.e., the right to do `DROP`, `GRANT`, `REVOKE`, etc.) are always implicit in being the owner, and cannot be granted or revoked. But the object owner can choose to revoke his own ordinary privileges, for example to make a table read-only for himself as well as others.

Ordinarily, only the object's owner (or a superuser) can grant or revoke privileges on an object. However, it is possible to grant a privilege "with grant option", which gives the recipient the right to grant it in turn to others. If the grant option is subsequently revoked then all who received the privilege from that recipient (directly or through a chain of grants) will lose the privilege. For details see the GRANT and REVOKE reference pages.

5.7. Schemas

A PostgreSQL database cluster contains one or more named databases. Users and groups of users are shared across the entire cluster, but no other data is shared across databases. Any given client con-

nection to the server can access only the data in a single database, the one specified in the connection request.

> **Note:** Users of a cluster do not necessarily have the privilege to access every database in the cluster. Sharing of user names means that there cannot be different users named, say, `joe` in two databases in the same cluster; but the system can be configured to allow `joe` access to only some of the databases.

A database contains one or more named *schemas*, which in turn contain tables. Schemas also contain other kinds of named objects, including data types, functions, and operators. The same object name can be used in different schemas without conflict; for example, both `schema1` and `myschema` can contain tables named `mytable`. Unlike databases, schemas are not rigidly separated: a user can access objects in any of the schemas in the database he is connected to, if he has privileges to do so.

There are several reasons why one might want to use schemas:

- To allow many users to use one database without interfering with each other.
- To organize database objects into logical groups to make them more manageable.
- Third-party applications can be put into separate schemas so they do not collide with the names of other objects.

Schemas are analogous to directories at the operating system level, except that schemas cannot be nested.

5.7.1. Creating a Schema

To create a schema, use the CREATE SCHEMA command. Give the schema a name of your choice. For example:

```
CREATE SCHEMA myschema;
```

To create or access objects in a schema, write a *qualified name* consisting of the schema name and table name separated by a dot:

```
schema.table
```

This works anywhere a table name is expected, including the table modification commands and the data access commands discussed in the following chapters. (For brevity we will speak of tables only, but the same ideas apply to other kinds of named objects, such as types and functions.)

Actually, the even more general syntax

```
database.schema.table
```

can be used too, but at present this is just for *pro forma* compliance with the SQL standard. If you write a database name, it must be the same as the database you are connected to.

So to create a table in the new schema, use:

```
CREATE TABLE myschema.mytable (
 ...
);
```

To drop a schema if it's empty (all objects in it have been dropped), use:

```
DROP SCHEMA myschema;
```

To drop a schema including all contained objects, use:

```
DROP SCHEMA myschema CASCADE;
```

See Section 5.12 for a description of the general mechanism behind this.

Often you will want to create a schema owned by someone else (since this is one of the ways to restrict the activities of your users to well-defined namespaces). The syntax for that is:

```
CREATE SCHEMA schemaname AUTHORIZATION username;
```

You can even omit the schema name, in which case the schema name will be the same as the user name. See Section 5.7.6 for how this can be useful.

Schema names beginning with `pg_` are reserved for system purposes and cannot be created by users.

5.7.2. The Public Schema

In the previous sections we created tables without specifying any schema names. By default such tables (and other objects) are automatically put into a schema named "public". Every new database contains such a schema. Thus, the following are equivalent:

```
CREATE TABLE products ( ... );
```

and:

```
CREATE TABLE public.products ( ... );
```

5.7.3. The Schema Search Path

Qualified names are tedious to write, and it's often best not to wire a particular schema name into applications anyway. Therefore tables are often referred to by *unqualified names*, which consist of just the table name. The system determines which table is meant by following a *search path*, which is a list of schemas to look in. The first matching table in the search path is taken to be the one wanted. If there is no match in the search path, an error is reported, even if matching table names exist in other schemas in the database.

The first schema named in the search path is called the current schema. Aside from being the first schema searched, it is also the schema in which new tables will be created if the `CREATE TABLE` command does not specify a schema name.

To show the current search path, use the following command:

```
SHOW search_path;
```

In the default setup this returns:

```
 search_path
```

```
--------------
 "$user",public
```

The first element specifies that a schema with the same name as the current user is to be searched. If no such schema exists, the entry is ignored. The second element refers to the public schema that we have seen already.

The first schema in the search path that exists is the default location for creating new objects. That is the reason that by default objects are created in the public schema. When objects are referenced in any other context without schema qualification (table modification, data modification, or query commands) the search path is traversed until a matching object is found. Therefore, in the default configuration, any unqualified access again can only refer to the public schema.

To put our new schema in the path, we use:

```
SET search_path TO myschema,public;
```

(We omit the `$user` here because we have no immediate need for it.) And then we can access the table without schema qualification:

```
DROP TABLE mytable;
```

Also, since `myschema` is the first element in the path, new objects would by default be created in it.

We could also have written:

```
SET search_path TO myschema;
```

Then we no longer have access to the public schema without explicit qualification. There is nothing special about the public schema except that it exists by default. It can be dropped, too.

See also Section 9.25 for other ways to manipulate the schema search path.

The search path works in the same way for data type names, function names, and operator names as it does for table names. Data type and function names can be qualified in exactly the same way as table names. If you need to write a qualified operator name in an expression, there is a special provision: you must write

```
OPERATOR(schema.operator)
```

This is needed to avoid syntactic ambiguity. An example is:

```
SELECT 3 OPERATOR(pg_catalog.+) 4;
```

In practice one usually relies on the search path for operators, so as not to have to write anything so ugly as that.

5.7.4. Schemas and Privileges

By default, users cannot access any objects in schemas they do not own. To allow that, the owner of the schema must grant the `USAGE` privilege on the schema. To allow users to make use of the objects in the schema, additional privileges might need to be granted, as appropriate for the object.

A user can also be allowed to create objects in someone else's schema. To allow that, the `CREATE` privilege on the schema needs to be granted. Note that by default, everyone has `CREATE` and `USAGE` privileges on the schema `public`. This allows all users that are able to connect to a given database to create objects in its `public` schema. If you do not want to allow that, you can revoke that privilege:

```
REVOKE CREATE ON SCHEMA public FROM PUBLIC;
```

(The first "public" is the schema, the second "public" means "every user". In the first sense it is an identifier, in the second sense it is a key word, hence the different capitalization; recall the guidelines from Section 4.1.1.)

5.7.5. The System Catalog Schema

In addition to `public` and user-created schemas, each database contains a `pg_catalog` schema, which contains the system tables and all the built-in data types, functions, and operators. `pg_catalog` is always effectively part of the search path. If it is not named explicitly in the path then it is implicitly searched *before* searching the path's schemas. This ensures that built-in names will always be findable. However, you can explicitly place `pg_catalog` at the end of your search path if you prefer to have user-defined names override built-in names.

Since system table names begin with `pg_`, it is best to avoid such names to ensure that you won't suffer a conflict if some future version defines a system table named the same as your table. (With the default search path, an unqualified reference to your table name would then be resolved as the system table instead.) System tables will continue to follow the convention of having names beginning with `pg_`, so that they will not conflict with unqualified user-table names so long as users avoid the `pg_` prefix.

5.7.6. Usage Patterns

Schemas can be used to organize your data in many ways. There are a few usage patterns that are recommended and are easily supported by the default configuration:

- If you do not create any schemas then all users access the public schema implicitly. This simulates the situation where schemas are not available at all. This setup is mainly recommended when there is only a single user or a few cooperating users in a database. This setup also allows smooth transition from the non-schema-aware world.
- You can create a schema for each user with the same name as that user. Recall that the default search path starts with `$user`, which resolves to the user name. Therefore, if each user has a separate schema, they access their own schemas by default.

  If you use this setup then you might also want to revoke access to the public schema (or drop it altogether), so users are truly constrained to their own schemas.
- To install shared applications (tables to be used by everyone, additional functions provided by third parties, etc.), put them into separate schemas. Remember to grant appropriate privileges to allow the other users to access them. Users can then refer to these additional objects by qualifying the names with a schema name, or they can put the additional schemas into their search path, as they choose.

5.7.7. Portability

In the SQL standard, the notion of objects in the same schema being owned by different users does not exist. Moreover, some implementations do not allow you to create schemas that have a different

name than their owner. In fact, the concepts of schema and user are nearly equivalent in a database system that implements only the basic schema support specified in the standard. Therefore, many users consider qualified names to really consist of *username*.*tablename*. This is how PostgreSQL will effectively behave if you create a per-user schema for every user.

Also, there is no concept of a `public` schema in the SQL standard. For maximum conformance to the standard, you should not use (perhaps even remove) the `public` schema.

Of course, some SQL database systems might not implement schemas at all, or provide namespace support by allowing (possibly limited) cross-database access. If you need to work with those systems, then maximum portability would be achieved by not using schemas at all.

5.8. Inheritance

PostgreSQL implements table inheritance, which can be a useful tool for database designers. (SQL:1999 and later define a type inheritance feature, which differs in many respects from the features described here.)

Let's start with an example: suppose we are trying to build a data model for cities. Each state has many cities, but only one capital. We want to be able to quickly retrieve the capital city for any particular state. This can be done by creating two tables, one for state capitals and one for cities that are not capitals. However, what happens when we want to ask for data about a city, regardless of whether it is a capital or not? The inheritance feature can help to resolve this problem. We define the `capitals` table so that it inherits from `cities`:

```
CREATE TABLE cities (
    name            text,
    population      float,
    altitude        int     -- in feet
);

CREATE TABLE capitals (
    state           char(2)
) INHERITS (cities);
```

In this case, the `capitals` table *inherits* all the columns of its parent table, `cities`. State capitals also have an extra column, `state`, that shows their state.

In PostgreSQL, a table can inherit from zero or more other tables, and a query can reference either all rows of a table or all rows of a table plus all of its descendant tables. The latter behavior is the default. For example, the following query finds the names of all cities, including state capitals, that are located at an altitude over 500 feet:

```
SELECT name, altitude
    FROM cities
    WHERE altitude > 500;
```

Given the sample data from the PostgreSQL tutorial (see Section 2.1), this returns:

```
   name    | altitude
-----------+----------
 Las Vegas |     2174
 Mariposa  |     1953
 Madison   |      845
```

On the other hand, the following query finds all the cities that are not state capitals and are situated at an altitude over 500 feet:

```
SELECT name, altitude
    FROM ONLY cities
    WHERE altitude > 500;

   name    | altitude
-----------+----------
 Las Vegas |     2174
 Mariposa  |     1953
```

Here the `ONLY` keyword indicates that the query should apply only to `cities`, and not any tables below `cities` in the inheritance hierarchy. Many of the commands that we have already discussed — `SELECT`, `UPDATE` and `DELETE` — support the `ONLY` keyword.

You can also write the table name with a trailing `*` to explicitly specify that descendant tables are included:

```
SELECT name, altitude
    FROM cities*
    WHERE altitude > 500;
```

Writing `*` is not necessary, since this behavior is the default (unless you have changed the setting of the sql_inheritance configuration option). However writing `*` might be useful to emphasize that additional tables will be searched.

In some cases you might wish to know which table a particular row originated from. There is a system column called `tableoid` in each table which can tell you the originating table:

```
SELECT c.tableoid, c.name, c.altitude
FROM cities c
WHERE c.altitude > 500;
```

which returns:

```
 tableoid |   name    | altitude
----------+-----------+----------
   139793 | Las Vegas |     2174
   139793 | Mariposa  |     1953
   139798 | Madison   |      845
```

(If you try to reproduce this example, you will probably get different numeric OIDs.) By doing a join with `pg_class` you can see the actual table names:

```
SELECT p.relname, c.name, c.altitude
FROM cities c, pg_class p
WHERE c.altitude > 500 AND c.tableoid = p.oid;
```

which returns:

```
 relname  |   name    | altitude
----------+-----------+----------
 cities   | Las Vegas |     2174
 cities   | Mariposa  |     1953
```

```
 capitals | Madison   |      845
```

Inheritance does not automatically propagate data from INSERT or COPY commands to other tables in the inheritance hierarchy. In our example, the following INSERT statement will fail:

```
INSERT INTO cities (name, population, altitude, state)
VALUES ('New York', NULL, NULL, 'NY');
```

We might hope that the data would somehow be routed to the capitals table, but this does not happen: INSERT always inserts into exactly the table specified. In some cases it is possible to redirect the insertion using a rule (see Chapter 38). However that does not help for the above case because the cities table does not contain the column state, and so the command will be rejected before the rule can be applied.

All check constraints and not-null constraints on a parent table are automatically inherited by its children. Other types of constraints (unique, primary key, and foreign key constraints) are not inherited.

A table can inherit from more than one parent table, in which case it has the union of the columns defined by the parent tables. Any columns declared in the child table's definition are added to these. If the same column name appears in multiple parent tables, or in both a parent table and the child's definition, then these columns are "merged" so that there is only one such column in the child table. To be merged, columns must have the same data types, else an error is raised. The merged column will have copies of all the check constraints coming from any one of the column definitions it came from, and will be marked not-null if any of them are.

Table inheritance is typically established when the child table is created, using the INHERITS clause of the CREATE TABLE statement. Alternatively, a table which is already defined in a compatible way can have a new parent relationship added, using the INHERIT variant of ALTER TABLE. To do this the new child table must already include columns with the same names and types as the columns of the parent. It must also include check constraints with the same names and check expressions as those of the parent. Similarly an inheritance link can be removed from a child using the NO INHERIT variant of ALTER TABLE. Dynamically adding and removing inheritance links like this can be useful when the inheritance relationship is being used for table partitioning (see Section 5.9).

One convenient way to create a compatible table that will later be made a new child is to use the LIKE clause in CREATE TABLE. This creates a new table with the same columns as the source table. If there are any CHECK constraints defined on the source table, the INCLUDING CONSTRAINTS option to LIKE should be specified, as the new child must have constraints matching the parent to be considered compatible.

A parent table cannot be dropped while any of its children remain. Neither can columns or check constraints of child tables be dropped or altered if they are inherited from any parent tables. If you wish to remove a table and all of its descendants, one easy way is to drop the parent table with the CASCADE option.

ALTER TABLE will propagate any changes in column data definitions and check constraints down the inheritance hierarchy. Again, dropping columns that are depended on by other tables is only possible when using the CASCADE option. ALTER TABLE follows the same rules for duplicate column merging and rejection that apply during CREATE TABLE.

Note how table access permissions are handled. Querying a parent table can automatically access data in child tables without further access privilege checking. This preserves the appearance that the data is (also) in the parent table. Accessing the child tables directly is, however, not automatically allowed and would require further privileges to be granted.

5.8.1. Caveats

Note that not all SQL commands are able to work on inheritance hierarchies. Commands that are used for data querying, data modification, or schema modification (e.g., SELECT, UPDATE, DELETE, most variants of ALTER TABLE, but not INSERT or ALTER TABLE ... RENAME) typically default to including child tables and support the ONLY notation to exclude them. Commands that do database maintenance and tuning (e.g., REINDEX, VACUUM) typically only work on individual, physical tables and do not support recursing over inheritance hierarchies. The respective behavior of each individual command is documented in its reference page (Reference I, *SQL Commands*).

A serious limitation of the inheritance feature is that indexes (including unique constraints) and foreign key constraints only apply to single tables, not to their inheritance children. This is true on both the referencing and referenced sides of a foreign key constraint. Thus, in the terms of the above example:

- If we declared cities.name to be UNIQUE or a PRIMARY KEY, this would not stop the capitals table from having rows with names duplicating rows in cities. And those duplicate rows would by default show up in queries from cities. In fact, by default capitals would have no unique constraint at all, and so could contain multiple rows with the same name. You could add a unique constraint to capitals, but this would not prevent duplication compared to cities.
- Similarly, if we were to specify that cities.name REFERENCES some other table, this constraint would not automatically propagate to capitals. In this case you could work around it by manually adding the same REFERENCES constraint to capitals.
- Specifying that another table's column REFERENCES cities(name) would allow the other table to contain city names, but not capital names. There is no good workaround for this case.

These deficiencies will probably be fixed in some future release, but in the meantime considerable care is needed in deciding whether inheritance is useful for your application.

5.9. Partitioning

PostgreSQL supports basic table partitioning. This section describes why and how to implement partitioning as part of your database design.

5.9.1. Overview

Partitioning refers to splitting what is logically one large table into smaller physical pieces. Partitioning can provide several benefits:

- Query performance can be improved dramatically in certain situations, particularly when most of the heavily accessed rows of the table are in a single partition or a small number of partitions. The partitioning substitutes for leading columns of indexes, reducing index size and making it more likely that the heavily-used parts of the indexes fit in memory.
- When queries or updates access a large percentage of a single partition, performance can be improved by taking advantage of sequential scan of that partition instead of using an index and random access reads scattered across the whole table.
- Bulk loads and deletes can be accomplished by adding or removing partitions, if that requirement is planned into the partitioning design. ALTER TABLE NO INHERIT and DROP TABLE are both far

faster than a bulk operation. These commands also entirely avoid the VACUUM overhead caused by a bulk DELETE.

- Seldom-used data can be migrated to cheaper and slower storage media.

The benefits will normally be worthwhile only when a table would otherwise be very large. The exact point at which a table will benefit from partitioning depends on the application, although a rule of thumb is that the size of the table should exceed the physical memory of the database server.

Currently, PostgreSQL supports partitioning via table inheritance. Each partition must be created as a child table of a single parent table. The parent table itself is normally empty; it exists just to represent the entire data set. You should be familiar with inheritance (see Section 5.8) before attempting to set up partitioning.

The following forms of partitioning can be implemented in PostgreSQL:

Range Partitioning

The table is partitioned into "ranges" defined by a key column or set of columns, with no overlap between the ranges of values assigned to different partitions. For example one might partition by date ranges, or by ranges of identifiers for particular business objects.

List Partitioning

The table is partitioned by explicitly listing which key values appear in each partition.

5.9.2. Implementing Partitioning

To set up a partitioned table, do the following:

1. Create the "master" table, from which all of the partitions will inherit.

   This table will contain no data. Do not define any check constraints on this table, unless you intend them to be applied equally to all partitions. There is no point in defining any indexes or unique constraints on it, either.
2. Create several "child" tables that each inherit from the master table. Normally, these tables will not add any columns to the set inherited from the master.

   We will refer to the child tables as partitions, though they are in every way normal PostgreSQL tables.
3. Add table constraints to the partition tables to define the allowed key values in each partition.

   Typical examples would be:

   ```
   CHECK ( x = 1 )
   CHECK ( county IN ( 'Oxfordshire', 'Buckinghamshire', 'Warwickshire' ))
   CHECK ( outletID >= 100 AND outletID < 200 )
   ```

   Ensure that the constraints guarantee that there is no overlap between the key values permitted in different partitions. A common mistake is to set up range constraints like:

   ```
   CHECK ( outletID BETWEEN 100 AND 200 )
   CHECK ( outletID BETWEEN 200 AND 300 )
   ```

   This is wrong since it is not clear which partition the key value 200 belongs in.

   Note that there is no difference in syntax between range and list partitioning; those terms are descriptive only.

4. For each partition, create an index on the key column(s), as well as any other indexes you might want. (The key index is not strictly necessary, but in most scenarios it is helpful. If you intend the key values to be unique then you should always create a unique or primary-key constraint for each partition.)
5. Optionally, define a trigger or rule to redirect data inserted into the master table to the appropriate partition.
6. Ensure that the constraint_exclusion configuration parameter is not disabled in `postgresql.conf`. If it is, queries will not be optimized as desired.

For example, suppose we are constructing a database for a large ice cream company. The company measures peak temperatures every day as well as ice cream sales in each region. Conceptually, we want a table like:

```
CREATE TABLE measurement (
    city_id         int not null,
    logdate         date not null,
    peaktemp        int,
    unitsales       int
);
```

We know that most queries will access just the last week's, month's or quarter's data, since the main use of this table will be to prepare online reports for management. To reduce the amount of old data that needs to be stored, we decide to only keep the most recent 3 years worth of data. At the beginning of each month we will remove the oldest month's data.

In this situation we can use partitioning to help us meet all of our different requirements for the measurements table. Following the steps outlined above, partitioning can be set up as follows:

1. The master table is the `measurement` table, declared exactly as above.
2. Next we create one partition for each active month:

   ```
   CREATE TABLE measurement_y2006m02 ( ) INHERITS (measurement);
   CREATE TABLE measurement_y2006m03 ( ) INHERITS (measurement);
   ...
   CREATE TABLE measurement_y2007m11 ( ) INHERITS (measurement);
   CREATE TABLE measurement_y2007m12 ( ) INHERITS (measurement);
   CREATE TABLE measurement_y2008m01 ( ) INHERITS (measurement);
   ```

   Each of the partitions are complete tables in their own right, but they inherit their definitions from the `measurement` table.

   This solves one of our problems: deleting old data. Each month, all we will need to do is perform a `DROP TABLE` on the oldest child table and create a new child table for the new month's data.
3. We must provide non-overlapping table constraints. Rather than just creating the partition tables as above, the table creation script should really be:

   ```
   CREATE TABLE measurement_y2006m02 (
       CHECK ( logdate >= DATE '2006-02-01' AND logdate < DATE '2006-03-01' )
   ) INHERITS (measurement);
   CREATE TABLE measurement_y2006m03 (
       CHECK ( logdate >= DATE '2006-03-01' AND logdate < DATE '2006-04-01' )
   ) INHERITS (measurement);
   ...
   CREATE TABLE measurement_y2007m11 (
       CHECK ( logdate >= DATE '2007-11-01' AND logdate < DATE '2007-12-01' )
   ) INHERITS (measurement);
   ```

```
CREATE TABLE measurement_y2007m12 (
    CHECK ( logdate >= DATE '2007-12-01' AND logdate < DATE '2008-01-01' )
) INHERITS (measurement);
CREATE TABLE measurement_y2008m01 (
    CHECK ( logdate >= DATE '2008-01-01' AND logdate < DATE '2008-02-01' )
) INHERITS (measurement);
```

4. We probably need indexes on the key columns too:

```
CREATE INDEX measurement_y2006m02_logdate ON measurement_y2006m02 (logdate);
CREATE INDEX measurement_y2006m03_logdate ON measurement_y2006m03 (logdate);
...
CREATE INDEX measurement_y2007m11_logdate ON measurement_y2007m11 (logdate);
CREATE INDEX measurement_y2007m12_logdate ON measurement_y2007m12 (logdate);
CREATE INDEX measurement_y2008m01_logdate ON measurement_y2008m01 (logdate);
```

   We choose not to add further indexes at this time.

5. We want our application to be able to say `INSERT INTO measurement ...` and have the data be redirected into the appropriate partition table. We can arrange that by attaching a suitable trigger function to the master table. If data will be added only to the latest partition, we can use a very simple trigger function:

```
CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
BEGIN
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;
```

   After creating the function, we create a trigger which calls the trigger function:

```
CREATE TRIGGER insert_measurement_trigger
    BEFORE INSERT ON measurement
    FOR EACH ROW EXECUTE PROCEDURE measurement_insert_trigger();
```

   We must redefine the trigger function each month so that it always points to the current partition. The trigger definition does not need to be updated, however.

   We might want to insert data and have the server automatically locate the partition into which the row should be added. We could do this with a more complex trigger function, for example:

```
CREATE OR REPLACE FUNCTION measurement_insert_trigger()
RETURNS TRIGGER AS $$
BEGIN
    IF ( NEW.logdate >= DATE '2006-02-01' AND
         NEW.logdate < DATE '2006-03-01' ) THEN
        INSERT INTO measurement_y2006m02 VALUES (NEW.*);
    ELSIF ( NEW.logdate >= DATE '2006-03-01' AND
            NEW.logdate < DATE '2006-04-01' ) THEN
        INSERT INTO measurement_y2006m03 VALUES (NEW.*);
    ...
    ELSIF ( NEW.logdate >= DATE '2008-01-01' AND
            NEW.logdate < DATE '2008-02-01' ) THEN
        INSERT INTO measurement_y2008m01 VALUES (NEW.*);
    ELSE
        RAISE EXCEPTION 'Date out of range.  Fix the measurement_insert_trigger() fun
    END IF;
    RETURN NULL;
END;
$$
LANGUAGE plpgsql;
```

The trigger definition is the same as before. Note that each `IF` test must exactly match the `CHECK` constraint for its partition.

While this function is more complex than the single-month case, it doesn't need to be updated as often, since branches can be added in advance of being needed.

> **Note:** In practice it might be best to check the newest partition first, if most inserts go into that partition. For simplicity we have shown the trigger's tests in the same order as in other parts of this example.

As we can see, a complex partitioning scheme could require a substantial amount of DDL. In the above example we would be creating a new partition each month, so it might be wise to write a script that generates the required DDL automatically.

5.9.3. Managing Partitions

Normally the set of partitions established when initially defining the table are not intended to remain static. It is common to want to remove old partitions of data and periodically add new partitions for new data. One of the most important advantages of partitioning is precisely that it allows this otherwise painful task to be executed nearly instantaneously by manipulating the partition structure, rather than physically moving large amounts of data around.

The simplest option for removing old data is simply to drop the partition that is no longer necessary:

```
DROP TABLE measurement_y2006m02;
```

This can very quickly delete millions of records because it doesn't have to individually delete every record.

Another option that is often preferable is to remove the partition from the partitioned table but retain access to it as a table in its own right:

```
ALTER TABLE measurement_y2006m02 NO INHERIT measurement;
```

This allows further operations to be performed on the data before it is dropped. For example, this is often a useful time to back up the data using `COPY`, pg_dump, or similar tools. It might also be a useful time to aggregate data into smaller formats, perform other data manipulations, or run reports.

Similarly we can add a new partition to handle new data. We can create an empty partition in the partitioned table just as the original partitions were created above:

```
CREATE TABLE measurement_y2008m02 (
    CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE '2008-03-01' )
) INHERITS (measurement);
```

As an alternative, it is sometimes more convenient to create the new table outside the partition structure, and make it a proper partition later. This allows the data to be loaded, checked, and transformed prior to it appearing in the partitioned table:

```
CREATE TABLE measurement_y2008m02
  (LIKE measurement INCLUDING DEFAULTS INCLUDING CONSTRAINTS);
ALTER TABLE measurement_y2008m02 ADD CONSTRAINT y2008m02
```

```
   CHECK ( logdate >= DATE '2008-02-01' AND logdate < DATE '2008-03-01' );
\copy measurement_y2008m02 from 'measurement_y2008m02'
-- possibly some other data preparation work
ALTER TABLE measurement_y2008m02 INHERIT measurement;
```

5.9.4. Partitioning and Constraint Exclusion

Constraint exclusion is a query optimization technique that improves performance for partitioned tables defined in the fashion described above. As an example:

```
SET constraint_exclusion = on;
SELECT count(*) FROM measurement WHERE logdate >= DATE '2008-01-01';
```

Without constraint exclusion, the above query would scan each of the partitions of the `measurement` table. With constraint exclusion enabled, the planner will examine the constraints of each partition and try to prove that the partition need not be scanned because it could not contain any rows meeting the query's `WHERE` clause. When the planner can prove this, it excludes the partition from the query plan.

You can use the `EXPLAIN` command to show the difference between a plan with `constraint_exclusion` on and a plan with it off. A typical unoptimized plan for this type of table setup is:

```
SET constraint_exclusion = off;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE '2008-01-01';

                                        QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate  (cost=158.66..158.68 rows=1 width=0)
   ->  Append  (cost=0.00..151.88 rows=2715 width=0)
         ->  Seq Scan on measurement  (cost=0.00..30.38 rows=543 width=0)
               Filter: (logdate >= '2008-01-01'::date)
         ->  Seq Scan on measurement_y2006m02 measurement  (cost=0.00..30.38 rows=543 wi
               Filter: (logdate >= '2008-01-01'::date)
         ->  Seq Scan on measurement_y2006m03 measurement  (cost=0.00..30.38 rows=543 wi
               Filter: (logdate >= '2008-01-01'::date)
...
         ->  Seq Scan on measurement_y2007m12 measurement  (cost=0.00..30.38 rows=543 wi
               Filter: (logdate >= '2008-01-01'::date)
         ->  Seq Scan on measurement_y2008m01 measurement  (cost=0.00..30.38 rows=543 wi
               Filter: (logdate >= '2008-01-01'::date)
```

Some or all of the partitions might use index scans instead of full-table sequential scans, but the point here is that there is no need to scan the older partitions at all to answer this query. When we enable constraint exclusion, we get a significantly cheaper plan that will deliver the same answer:

```
SET constraint_exclusion = on;
EXPLAIN SELECT count(*) FROM measurement WHERE logdate >= DATE '2008-01-01';
                                        QUERY PLAN
-------------------------------------------------------------------------------------------
 Aggregate  (cost=63.47..63.48 rows=1 width=0)
   ->  Append  (cost=0.00..60.75 rows=1086 width=0)
         ->  Seq Scan on measurement  (cost=0.00..30.38 rows=543 width=0)
               Filter: (logdate >= '2008-01-01'::date)
```

```
->  Seq Scan on measurement_y2008m01 measurement  (cost=0.00..30.38 rows=543 wi
      Filter: (logdate >= '2008-01-01'::date)
```

Note that constraint exclusion is driven only by `CHECK` constraints, not by the presence of indexes. Therefore it isn't necessary to define indexes on the key columns. Whether an index needs to be created for a given partition depends on whether you expect that queries that scan the partition will generally scan a large part of the partition or just a small part. An index will be helpful in the latter case but not the former.

The default (and recommended) setting of constraint_exclusion is actually neither `on` nor `off`, but an intermediate setting called `partition`, which causes the technique to be applied only to queries that are likely to be working on partitioned tables. The `on` setting causes the planner to examine `CHECK` constraints in all queries, even simple ones that are unlikely to benefit.

5.9.5. Alternative Partitioning Methods

A different approach to redirecting inserts into the appropriate partition table is to set up rules, instead of a trigger, on the master table. For example:

```
CREATE RULE measurement_insert_y2006m02 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2006-02-01' AND logdate < DATE '2006-03-01' )
DO INSTEAD
    INSERT INTO measurement_y2006m02 VALUES (NEW.*);
...
CREATE RULE measurement_insert_y2008m01 AS
ON INSERT TO measurement WHERE
    ( logdate >= DATE '2008-01-01' AND logdate < DATE '2008-02-01' )
DO INSTEAD
    INSERT INTO measurement_y2008m01 VALUES (NEW.*);
```

A rule has significantly more overhead than a trigger, but the overhead is paid once per query rather than once per row, so this method might be advantageous for bulk-insert situations. In most cases, however, the trigger method will offer better performance.

Be aware that `COPY` ignores rules. If you want to use `COPY` to insert data, you'll need to copy into the correct partition table rather than into the master. `COPY` does fire triggers, so you can use it normally if you use the trigger approach.

Another disadvantage of the rule approach is that there is no simple way to force an error if the set of rules doesn't cover the insertion date; the data will silently go into the master table instead.

Partitioning can also be arranged using a `UNION ALL` view, instead of table inheritance. For example,

```
CREATE VIEW measurement AS
          SELECT * FROM measurement_y2006m02
UNION ALL SELECT * FROM measurement_y2006m03
...
UNION ALL SELECT * FROM measurement_y2007m11
UNION ALL SELECT * FROM measurement_y2007m12
UNION ALL SELECT * FROM measurement_y2008m01;
```

However, the need to recreate the view adds an extra step to adding and dropping individual partitions of the data set. In practice this method has little to recommend it compared to using inheritance.

5.9.6. Caveats

The following caveats apply to partitioned tables:

- There is no automatic way to verify that all of the `CHECK` constraints are mutually exclusive. It is safer to create code that generates partitions and creates and/or modifies associated objects than to write each by hand.
- The schemes shown here assume that the partition key column(s) of a row never change, or at least do not change enough to require it to move to another partition. An `UPDATE` that attempts to do that will fail because of the `CHECK` constraints. If you need to handle such cases, you can put suitable update triggers on the partition tables, but it makes management of the structure much more complicated.
- If you are using manual `VACUUM` or `ANALYZE` commands, don't forget that you need to run them on each partition individually. A command like:

  ```
  ANALYZE measurement;
  ```
  will only process the master table.

The following caveats apply to constraint exclusion:

- Constraint exclusion only works when the query's `WHERE` clause contains constants (or externally supplied parameters). For example, a comparison against a non-immutable function such as `CURRENT_TIMESTAMP` cannot be optimized, since the planner cannot know which partition the function value might fall into at run time.
- Keep the partitioning constraints simple, else the planner may not be able to prove that partitions don't need to be visited. Use simple equality conditions for list partitioning, or simple range tests for range partitioning, as illustrated in the preceding examples. A good rule of thumb is that partitioning constraints should contain only comparisons of the partitioning column(s) to constants using B-tree-indexable operators.
- All constraints on all partitions of the master table are examined during constraint exclusion, so large numbers of partitions are likely to increase query planning time considerably. Partitioning using these techniques will work well with up to perhaps a hundred partitions; don't try to use many thousands of partitions.

5.10. Foreign Data

PostgreSQL implements portions of the SQL/MED specification, allowing you to access data that resides outside PostgreSQL using regular SQL queries. Such data is referred to as *foreign data*. (Note that this usage is not to be confused with foreign keys, which are a type of constraint within the database.)

Foreign data is accessed with help from a *foreign data wrapper*. A foreign data wrapper is a library that can communicate with an external data source, hiding the details of connecting to the data source and obtaining data from it. There are some foreign data wrappers available as `contrib` modules; see Appendix F. Other kinds of foreign data wrappers might be found as third party products. If none of the existing foreign data wrappers suit your needs, you can write your own; see Chapter 53.

To access foreign data, you need to create a *foreign server* object, which defines how to connect to a particular external data source according to the set of options used by its supporting foreign data wrapper. Then you need to create one or more *foreign tables*, which define the structure of the remote data. A foreign table can be used in queries just like a normal table, but a foreign table has no storage in the PostgreSQL server. Whenever it is used, PostgreSQL asks the foreign data wrapper to fetch data from the external source, or transmit data to the external source in the case of update commands.

Accessing remote data may require authenticating to the external data source. This information can be provided by a *user mapping*, which can provide additional data such as user names and passwords based on the current PostgreSQL role.

For additional information, see CREATE FOREIGN DATA WRAPPER, CREATE SERVER, CREATE USER MAPPING, and CREATE FOREIGN TABLE.

5.11. Other Database Objects

Tables are the central objects in a relational database structure, because they hold your data. But they are not the only objects that exist in a database. Many other kinds of objects can be created to make the use and management of the data more efficient or convenient. They are not discussed in this chapter, but we give you a list here so that you are aware of what is possible:

- Views
- Functions and operators
- Data types and domains
- Triggers and rewrite rules

Detailed information on these topics appears in Part V.

5.12. Dependency Tracking

When you create complex database structures involving many tables with foreign key constraints, views, triggers, functions, etc. you implicitly create a net of dependencies between the objects. For instance, a table with a foreign key constraint depends on the table it references.

To ensure the integrity of the entire database structure, PostgreSQL makes sure that you cannot drop objects that other objects still depend on. For example, attempting to drop the products table we had considered in Section 5.3.5, with the orders table depending on it, would result in an error message such as this:

```
DROP TABLE products;

NOTICE:  constraint orders_product_no_fkey on table orders depends on table products
ERROR:  cannot drop table products because other objects depend on it
HINT:  Use DROP ... CASCADE to drop the dependent objects too.
```

The error message contains a useful hint: if you do not want to bother deleting all the dependent objects individually, you can run:

```
DROP TABLE products CASCADE;
```

and all the dependent objects will be removed. In this case, it doesn't remove the orders table, it only removes the foreign key constraint. (If you want to check what `DROP ... CASCADE` will do, run `DROP` without `CASCADE` and read the `NOTICE` messages.)

All drop commands in PostgreSQL support specifying `CASCADE`. Of course, the nature of the possible dependencies varies with the type of the object. You can also write `RESTRICT` instead of `CASCADE` to get the default behavior, which is to prevent the dropping of objects that other objects depend on.

> **Note:** According to the SQL standard, specifying either `RESTRICT` or `CASCADE` is required. No database system actually enforces that rule, but whether the default behavior is `RESTRICT` or `CASCADE` varies across systems.

> **Note:** Foreign key constraint dependencies and serial column dependencies from PostgreSQL versions prior to 7.3 are *not* maintained or created during the upgrade process. All other dependency types will be properly created during an upgrade from a pre-7.3 database.

Chapter 6. Data Manipulation

The previous chapter discussed how to create tables and other structures to hold your data. Now it is time to fill the tables with data. This chapter covers how to insert, update, and delete table data. The chapter after this will finally explain how to extract your long-lost data from the database.

6.1. Inserting Data

When a table is created, it contains no data. The first thing to do before a database can be of much use is to insert data. Data is conceptually inserted one row at a time. Of course you can also insert more than one row, but there is no way to insert less than one row. Even if you know only some column values, a complete row must be created.

To create a new row, use the INSERT command. The command requires the table name and column values. For example, consider the products table from Chapter 5:

```
CREATE TABLE products (
    product_no integer,
    name text,
    price numeric
);
```

An example command to insert a row would be:

```
INSERT INTO products VALUES (1, 'Cheese', 9.99);
```

The data values are listed in the order in which the columns appear in the table, separated by commas. Usually, the data values will be literals (constants), but scalar expressions are also allowed.

The above syntax has the drawback that you need to know the order of the columns in the table. To avoid this you can also list the columns explicitly. For example, both of the following commands have the same effect as the one above:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese', 9.99);
INSERT INTO products (name, price, product_no) VALUES ('Cheese', 9.99, 1);
```

Many users consider it good practice to always list the column names.

If you don't have values for all the columns, you can omit some of them. In that case, the columns will be filled with their default values. For example:

```
INSERT INTO products (product_no, name) VALUES (1, 'Cheese');
INSERT INTO products VALUES (1, 'Cheese');
```

The second form is a PostgreSQL extension. It fills the columns from the left with as many values as are given, and the rest will be defaulted.

For clarity, you can also request default values explicitly, for individual columns or for the entire row:

```
INSERT INTO products (product_no, name, price) VALUES (1, 'Cheese', DEFAULT);
INSERT INTO products DEFAULT VALUES;
```

You can insert multiple rows in a single command:

```
INSERT INTO products (product_no, name, price) VALUES
```

```
(1, 'Cheese', 9.99),
(2, 'Bread', 1.99),
(3, 'Milk', 2.99);
```

Tip: When inserting a lot of data at the same time, considering using the COPY command. It is not as flexible as the INSERT command, but is more efficient. Refer to Section 14.4 for more information on improving bulk loading performance.

6.2. Updating Data

The modification of data that is already in the database is referred to as updating. You can update individual rows, all the rows in a table, or a subset of all rows. Each column can be updated separately; the other columns are not affected.

To update existing rows, use the UPDATE command. This requires three pieces of information:

1. The name of the table and column to update
2. The new value of the column
3. Which row(s) to update

Recall from Chapter 5 that SQL does not, in general, provide a unique identifier for rows. Therefore it is not always possible to directly specify which row to update. Instead, you specify which conditions a row must meet in order to be updated. Only if you have a primary key in the table (independent of whether you declared it or not) can you reliably address individual rows by choosing a condition that matches the primary key. Graphical database access tools rely on this fact to allow you to update rows individually.

For example, this command updates all products that have a price of 5 to have a price of 10:

```
UPDATE products SET price = 10 WHERE price = 5;
```

This might cause zero, one, or many rows to be updated. It is not an error to attempt an update that does not match any rows.

Let's look at that command in detail. First is the key word `UPDATE` followed by the table name. As usual, the table name can be schema-qualified, otherwise it is looked up in the path. Next is the key word `SET` followed by the column name, an equal sign, and the new column value. The new column value can be any scalar expression, not just a constant. For example, if you want to raise the price of all products by 10% you could use:

```
UPDATE products SET price = price * 1.10;
```

As you see, the expression for the new value can refer to the existing value(s) in the row. We also left out the `WHERE` clause. If it is omitted, it means that all rows in the table are updated. If it is present, only those rows that match the `WHERE` condition are updated. Note that the equals sign in the `SET` clause is an assignment while the one in the `WHERE` clause is a comparison, but this does not create any ambiguity. Of course, the `WHERE` condition does not have to be an equality test. Many other operators are available (see Chapter 9). But the expression needs to evaluate to a Boolean result.

You can update more than one column in an `UPDATE` command by listing more than one assignment in the `SET` clause. For example:

```
UPDATE mytable SET a = 5, b = 3, c = 1 WHERE a > 0;
```

6.3. Deleting Data

So far we have explained how to add data to tables and how to change data. What remains is to discuss how to remove data that is no longer needed. Just as adding data is only possible in whole rows, you can only remove entire rows from a table. In the previous section we explained that SQL does not provide a way to directly address individual rows. Therefore, removing rows can only be done by specifying conditions that the rows to be removed have to match. If you have a primary key in the table then you can specify the exact row. But you can also remove groups of rows matching a condition, or you can remove all rows in the table at once.

You use the DELETE command to remove rows; the syntax is very similar to the `UPDATE` command. For instance, to remove all rows from the products table that have a price of 10, use:

```
DELETE FROM products WHERE price = 10;
```

If you simply write:

```
DELETE FROM products;
```

then all rows in the table will be deleted! Caveat programmer.

Chapter 7. Queries

The previous chapters explained how to create tables, how to fill them with data, and how to manipulate that data. Now we finally discuss how to retrieve the data from the database.

7.1. Overview

The process of retrieving or the command to retrieve data from a database is called a *query*. In SQL the SELECT command is used to specify queries. The general syntax of the `SELECT` command is

```
[WITH with_queries] SELECT select_list FROM table_expression [sort_specification]
```

The following sections describe the details of the select list, the table expression, and the sort specification. `WITH` queries are treated last since they are an advanced feature.

A simple kind of query has the form:

```
SELECT * FROM table1;
```

Assuming that there is a table called `table1`, this command would retrieve all rows and all user-defined columns from `table1`. (The method of retrieval depends on the client application. For example, the psql program will display an ASCII-art table on the screen, while client libraries will offer functions to extract individual values from the query result.) The select list specification `*` means all columns that the table expression happens to provide. A select list can also select a subset of the available columns or make calculations using the columns. For example, if `table1` has columns named `a`, `b`, and `c` (and perhaps others) you can make the following query:

```
SELECT a, b + c FROM table1;
```

(assuming that `b` and `c` are of a numerical data type). See Section 7.3 for more details.

`FROM table1` is a simple kind of table expression: it reads just one table. In general, table expressions can be complex constructs of base tables, joins, and subqueries. But you can also omit the table expression entirely and use the `SELECT` command as a calculator:

```
SELECT 3 * 4;
```

This is more useful if the expressions in the select list return varying results. For example, you could call a function this way:

```
SELECT random();
```

7.2. Table Expressions

A *table expression* computes a table. The table expression contains a `FROM` clause that is optionally followed by `WHERE`, `GROUP BY`, and `HAVING` clauses. Trivial table expressions simply refer to a table on disk, a so-called base table, but more complex expressions can be used to modify or combine base tables in various ways.

The optional `WHERE`, `GROUP BY`, and `HAVING` clauses in the table expression specify a pipeline of successive transformations performed on the table derived in the `FROM` clause. All these transforma-

tions produce a virtual table that provides the rows that are passed to the select list to compute the output rows of the query.

7.2.1. The FROM Clause

The *FROM Clause* derives a table from one or more other tables given in a comma-separated table reference list.

```
FROM table_reference [, table_reference [, ...]]
```

A table reference can be a table name (possibly schema-qualified), or a derived table such as a subquery, a JOIN construct, or complex combinations of these. If more than one table reference is listed in the FROM clause, the tables are cross-joined (that is, the Cartesian product of their rows is formed; see below). The result of the FROM list is an intermediate virtual table that can then be subject to transformations by the WHERE, GROUP BY, and HAVING clauses and is finally the result of the overall table expression.

When a table reference names a table that is the parent of a table inheritance hierarchy, the table reference produces rows of not only that table but all of its descendant tables, unless the key word ONLY precedes the table name. However, the reference produces only the columns that appear in the named table — any columns added in subtables are ignored.

Instead of writing ONLY before the table name, you can write * after the table name to explicitly specify that descendant tables are included. Writing * is not necessary since that behavior is the default (unless you have changed the setting of the sql_inheritance configuration option). However writing * might be useful to emphasize that additional tables will be searched.

7.2.1.1. Joined Tables

A joined table is a table derived from two other (real or derived) tables according to the rules of the particular join type. Inner, outer, and cross-joins are available. The general syntax of a joined table is

```
T1 join_type T2 [ join_condition ]
```

Joins of all types can be chained together, or nested: either or both *T1* and *T2* can be joined tables. Parentheses can be used around JOIN clauses to control the join order. In the absence of parentheses, JOIN clauses nest left-to-right.

Join Types

Cross join

```
T1 CROSS JOIN T2
```

For every possible combination of rows from *T1* and *T2* (i.e., a Cartesian product), the joined table will contain a row consisting of all columns in *T1* followed by all columns in *T2*. If the tables have N and M rows respectively, the joined table will have N * M rows.

FROM *T1* CROSS JOIN *T2* is equivalent to FROM *T1* INNER JOIN *T2* ON TRUE (see below). It is also equivalent to FROM *T1*, *T2*.

> **Note:** This latter equivalence does not hold exactly when more than two tables appear, because JOIN binds more tightly than comma. For example FROM *T1* CROSS JOIN *T2* INNER JOIN *T3* ON *condition* is not the same as FROM *T1*, *T2* INNER JOIN *T3* ON *condition* because the *condition* can reference *T1* in the first case but not the second.

Qualified joins

```
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2 ON boolean_expression
T1 { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2 USING ( join column list )
T1 NATURAL { [INNER] | { LEFT | RIGHT | FULL } [OUTER] } JOIN T2
```

The words `INNER` and `OUTER` are optional in all forms. `INNER` is the default; `LEFT`, `RIGHT`, and `FULL` imply an outer join.

The *join condition* is specified in the `ON` or `USING` clause, or implicitly by the word `NATURAL`. The join condition determines which rows from the two source tables are considered to "match", as explained in detail below.

The possible types of qualified join are:

`INNER JOIN`

For each row R1 of T1, the joined table has a row for each row in T2 that satisfies the join condition with R1.

`LEFT OUTER JOIN`

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Thus, the joined table always has at least one row for each row in T1.

`RIGHT OUTER JOIN`

First, an inner join is performed. Then, for each row in T2 that does not satisfy the join condition with any row in T1, a joined row is added with null values in columns of T1. This is the converse of a left join: the result table will always have a row for each row in T2.

`FULL OUTER JOIN`

First, an inner join is performed. Then, for each row in T1 that does not satisfy the join condition with any row in T2, a joined row is added with null values in columns of T2. Also, for each row of T2 that does not satisfy the join condition with any row in T1, a joined row with null values in the columns of T1 is added.

The `ON` clause is the most general kind of join condition: it takes a Boolean value expression of the same kind as is used in a `WHERE` clause. A pair of rows from *T1* and *T2* match if the `ON` expression evaluates to true.

The `USING` clause is a shorthand that allows you to take advantage of the specific situation where both sides of the join use the same name for the joining column(s). It takes a comma-separated list of the shared column names and forms a join condition that includes an equality comparison for each one. For example, joining *T1* and *T2* with `USING (a, b)` produces the join condition `ON T1.a = T2.a AND T1.b = T2.b`.

Furthermore, the output of `JOIN USING` suppresses redundant columns: there is no need to print both of the matched columns, since they must have equal values. While `JOIN ON` produces all columns from *T1* followed by all columns from *T2*, `JOIN USING` produces one output column for each of the listed column pairs (in the listed order), followed by any remaining columns from *T1*, followed by any remaining columns from *T2*.

Finally, `NATURAL` is a shorthand form of `USING`: it forms a `USING` list consisting of all column names that appear in both input tables. As with `USING`, these columns appear only once in the output table. If there are no common column names, `NATURAL` behaves like `CROSS JOIN`.

> **Note:** `USING` is reasonably safe from column changes in the joined relations since only the listed columns are combined. `NATURAL` is considerably more risky since any schema changes to either relation that cause a new matching column name to be present will cause the join to combine that new column as well.

To put this together, assume we have tables `t1`:

```
 num | name
-----+------
   1 | a
   2 | b
   3 | c
```

and `t2`:

```
 num | value
-----+-------
   1 | xxx
   3 | yyy
   5 | zzz
```

then we get the following results for the various joins:

```
=> SELECT * FROM t1 CROSS JOIN t2;
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   1 | a    |   3 | yyy
   1 | a    |   5 | zzz
   2 | b    |   1 | xxx
   2 | b    |   3 | yyy
   2 | b    |   5 | zzz
   3 | c    |   1 | xxx
   3 | c    |   3 | yyy
   3 | c    |   5 | zzz
(9 rows)

=> SELECT * FROM t1 INNER JOIN t2 ON t1.num = t2.num;
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   3 | c    |   3 | yyy
(2 rows)

=> SELECT * FROM t1 INNER JOIN t2 USING (num);
 num | name | value
-----+------+-------
   1 | a    | xxx
   3 | c    | yyy
(2 rows)
```

```
=> SELECT * FROM t1 NATURAL INNER JOIN t2;
 num | name | value
-----+------+-------
   1 | a    | xxx
   3 | c    | yyy
(2 rows)

=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num;
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   2 | b    |     |
   3 | c    |   3 | yyy
(3 rows)

=> SELECT * FROM t1 LEFT JOIN t2 USING (num);
 num | name | value
-----+------+-------
   1 | a    | xxx
   2 | b    |
   3 | c    | yyy
(3 rows)

=> SELECT * FROM t1 RIGHT JOIN t2 ON t1.num = t2.num;
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   3 | c    |   3 | yyy
     |      |   5 | zzz
(3 rows)

=> SELECT * FROM t1 FULL JOIN t2 ON t1.num = t2.num;
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   2 | b    |     |
   3 | c    |   3 | yyy
     |      |   5 | zzz
(4 rows)
```

The join condition specified with `ON` can also contain conditions that do not relate directly to the join. This can prove useful for some queries but needs to be thought out carefully. For example:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num AND t2.value = 'xxx';
 num | name | num | value
-----+------+-----+-------
   1 | a    |   1 | xxx
   2 | b    |     |
   3 | c    |     |
(3 rows)
```

Notice that placing the restriction in the `WHERE` clause produces a different result:

```
=> SELECT * FROM t1 LEFT JOIN t2 ON t1.num = t2.num WHERE t2.value = 'xxx';
 num | name | num | value
```

```
-----+------+-----+-------
   1 | a    |   1 | xxx
(1 row)
```

This is because a restriction placed in the `ON` clause is processed *before* the join, while a restriction placed in the `WHERE` clause is processed *after* the join. That does not matter with inner joins, but it matters a lot with outer joins.

7.2.1.2. Table and Column Aliases

A temporary name can be given to tables and complex table references to be used for references to the derived table in the rest of the query. This is called a *table alias*.

To create a table alias, write

```
FROM table_reference AS alias
```

or

```
FROM table_reference alias
```

The `AS` key word is optional noise. *`alias`* can be any identifier.

A typical application of table aliases is to assign short identifiers to long table names to keep the join clauses readable. For example:

```
SELECT * FROM some_very_long_table_name s JOIN another_fairly_long_name a ON s.id = a.nu
```

The alias becomes the new name of the table reference so far as the current query is concerned — it is not allowed to refer to the table by the original name elsewhere in the query. Thus, this is not valid:

```
SELECT * FROM my_table AS m WHERE my_table.a > 5;    -- wrong
```

Table aliases are mainly for notational convenience, but it is necessary to use them when joining a table to itself, e.g.:

```
SELECT * FROM people AS mother JOIN people AS child ON mother.id = child.mother_id;
```

Additionally, an alias is required if the table reference is a subquery (see Section 7.2.1.3).

Parentheses are used to resolve ambiguities. In the following example, the first statement assigns the alias `b` to the second instance of `my_table`, but the second statement assigns the alias to the result of the join:

```
SELECT * FROM my_table AS a CROSS JOIN my_table AS b ...
SELECT * FROM (my_table AS a CROSS JOIN my_table) AS b ...
```

Another form of table aliasing gives temporary names to the columns of the table, as well as the table itself:

```
FROM table_reference [AS] alias ( column1 [, column2 [, ...]] )
```

If fewer column aliases are specified than the actual table has columns, the remaining columns are not renamed. This syntax is especially useful for self-joins or subqueries.

When an alias is applied to the output of a JOIN clause, the alias hides the original name(s) within the JOIN. For example:

```
SELECT a.* FROM my_table AS a JOIN your_table AS b ON ...
```

is valid SQL, but:

```
SELECT a.* FROM (my_table AS a JOIN your_table AS b ON ...) AS c
```

is not valid; the table alias a is not visible outside the alias c.

7.2.1.3. Subqueries

Subqueries specifying a derived table must be enclosed in parentheses and *must* be assigned a table alias name (as in Section 7.2.1.2). For example:

```
FROM (SELECT * FROM table1) AS alias_name
```

This example is equivalent to FROM table1 AS alias_name. More interesting cases, which cannot be reduced to a plain join, arise when the subquery involves grouping or aggregation.

A subquery can also be a VALUES list:

```
FROM (VALUES ('anne', 'smith'), ('bob', 'jones'), ('joe', 'blow'))
     AS names(first, last)
```

Again, a table alias is required. Assigning alias names to the columns of the VALUES list is optional, but is good practice. For more information see Section 7.7.

7.2.1.4. Table Functions

Table functions are functions that produce a set of rows, made up of either base data types (scalar types) or composite data types (table rows). They are used like a table, view, or subquery in the FROM clause of a query. Columns returned by table functions can be included in SELECT, JOIN, or WHERE clauses in the same manner as columns of a table, view, or subquery.

Table functions may also be combined using the ROWS FROM syntax, with the results returned in parallel columns; the number of result rows in this case is that of the largest function result, with smaller results padded with null values to match.

```
function_call [WITH ORDINALITY] [[AS] table_alias [(column_alias [, ... ])]]
ROWS FROM( function_call [, ... ] ) [WITH ORDINALITY] [[AS] table_alias [(column_alias [, ..
```

If the WITH ORDINALITY clause is specified, an additional column of type bigint will be added to the function result columns. This column numbers the rows of the function result set, starting from 1. (This is a generalization of the SQL-standard syntax for UNNEST ... WITH ORDINALITY.) By default, the ordinal column is called ordinality, but a different column name can be assigned to it using an AS clause.

The special table function UNNEST may be called with any number of array parameters, and it returns a corresponding number of columns, as if UNNEST (Section 9.18) had been called on each parameter separately and combined using the ROWS FROM construct.

```
UNNEST( array_expression [, ... ] ) [WITH ORDINALITY] [[AS] table_alias [(column_alias [, ..
```

If no *table_alias* is specified, the function name is used as the table name; in the case of a ROWS FROM() construct, the first function's name is used.

If column aliases are not supplied, then for a function returning a base data type, the column name is also the same as the function name. For a function returning a composite type, the result columns get the names of the individual attributes of the type.

Some examples:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);

CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;

SELECT * FROM getfoo(1) AS t1;

SELECT * FROM foo
    WHERE foosubid IN (
                        SELECT foosubid
                        FROM getfoo(foo.fooid) z
                        WHERE z.fooid = foo.fooid
                      );

CREATE VIEW vw_getfoo AS SELECT * FROM getfoo(1);

SELECT * FROM vw_getfoo;
```

In some cases it is useful to define table functions that can return different column sets depending on how they are invoked. To support this, the table function can be declared as returning the pseudotype record. When such a function is used in a query, the expected row structure must be specified in the query itself, so that the system can know how to parse and plan the query. This syntax looks like:

```
function_call [AS] alias (column_definition [, ... ])
function_call AS [alias] (column_definition [, ... ])
ROWS FROM( ... function_call AS (column_definition [, ... ]) [, ... ] )
```

When not using the ROWS FROM() syntax, the *column_definition* list replaces the column alias list that could otherwise be attached to the FROM item; the names in the column definitions serve as column aliases. When using the ROWS FROM() syntax, a *column_definition* list can be attached to each member function separately; or if there is only one member function and no WITH ORDINALITY clause, a *column_definition* list can be written in place of a column alias list following ROWS FROM().

Consider this example:

```
SELECT *
    FROM dblink('dbname=mydb', 'SELECT proname, prosrc FROM pg_proc')
      AS t1(proname name, prosrc text)
    WHERE proname LIKE 'bytea%';
```

The dblink function (part of the dblink module) executes a remote query. It is declared to return `record` since it might be used for any kind of query. The actual column set must be specified in the calling query so that the parser knows, for example, what `*` should expand to.

7.2.1.5. `LATERAL` Subqueries

Subqueries appearing in `FROM` can be preceded by the key word `LATERAL`. This allows them to reference columns provided by preceding `FROM` items. (Without `LATERAL`, each subquery is evaluated independently and so cannot cross-reference any other `FROM` item.)

Table functions appearing in `FROM` can also be preceded by the key word `LATERAL`, but for functions the key word is optional; the function's arguments can contain references to columns provided by preceding `FROM` items in any case.

A `LATERAL` item can appear at top level in the `FROM` list, or within a `JOIN` tree. In the latter case it can also refer to any items that are on the left-hand side of a `JOIN` that it is on the right-hand side of.

When a `FROM` item contains `LATERAL` cross-references, evaluation proceeds as follows: for each row of the `FROM` item providing the cross-referenced column(s), or set of rows of multiple `FROM` items providing the columns, the `LATERAL` item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

A trivial example of `LATERAL` is

```
SELECT * FROM foo, LATERAL (SELECT * FROM bar WHERE bar.id = foo.bar_id) ss;
```

This is not especially useful since it has exactly the same result as the more conventional

```
SELECT * FROM foo, bar WHERE bar.id = foo.bar_id;
```

`LATERAL` is primarily useful when the cross-referenced column is necessary for computing the row(s) to be joined. A common application is providing an argument value for a set-returning function. For example, supposing that `vertices(polygon)` returns the set of vertices of a polygon, we could identify close-together vertices of polygons stored in a table with:

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1, polygons p2,
     LATERAL vertices(p1.poly) v1,
     LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

This query could also be written

```
SELECT p1.id, p2.id, v1, v2
FROM polygons p1 CROSS JOIN LATERAL vertices(p1.poly) v1,
     polygons p2 CROSS JOIN LATERAL vertices(p2.poly) v2
WHERE (v1 <-> v2) < 10 AND p1.id != p2.id;
```

or in several other equivalent formulations. (As already mentioned, the `LATERAL` key word is unnecessary in this example, but we use it for clarity.)

It is often particularly handy to `LEFT JOIN` to a `LATERAL` subquery, so that source rows will appear in the result even if the `LATERAL` subquery produces no rows for them. For example, if `get_product_names()` returns the names of products made by a manufacturer, but some manufacturers in our table currently produce no products, we could find out which ones those are like this:

```
SELECT m.name
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id) pname ON true
WHERE pname IS NULL;
```

7.2.2. The WHERE Clause

The syntax of the *WHERE Clause* is

```
WHERE search_condition
```

where *search_condition* is any value expression (see Section 4.2) that returns a value of type boolean.

After the processing of the FROM clause is done, each row of the derived virtual table is checked against the search condition. If the result of the condition is true, the row is kept in the output table, otherwise (i.e., if the result is false or null) it is discarded. The search condition typically references at least one column of the table generated in the FROM clause; this is not required, but otherwise the WHERE clause will be fairly useless.

> **Note:** The join condition of an inner join can be written either in the WHERE clause or in the JOIN clause. For example, these table expressions are equivalent:
>
> ```
> FROM a, b WHERE a.id = b.id AND b.val > 5
> ```
>
> and:
>
> ```
> FROM a INNER JOIN b ON (a.id = b.id) WHERE b.val > 5
> ```
>
> or perhaps even:
>
> ```
> FROM a NATURAL JOIN b WHERE b.val > 5
> ```
>
> Which one of these you use is mainly a matter of style. The JOIN syntax in the FROM clause is probably not as portable to other SQL database management systems, even though it is in the SQL standard. For outer joins there is no choice: they must be done in the FROM clause. The ON or USING clause of an outer join is *not* equivalent to a WHERE condition, because it results in the addition of rows (for unmatched input rows) as well as the removal of rows in the final result.

Here are some examples of WHERE clauses:

```
SELECT ... FROM fdt WHERE c1 > 5

SELECT ... FROM fdt WHERE c1 IN (1, 2, 3)

SELECT ... FROM fdt WHERE c1 IN (SELECT c1 FROM t2)

SELECT ... FROM fdt WHERE c1 IN (SELECT c3 FROM t2 WHERE c2 = fdt.c1 + 10)

SELECT ... FROM fdt WHERE c1 BETWEEN (SELECT c3 FROM t2 WHERE c2 = fdt.c1 + 10) AND 100
```

```
SELECT ... FROM fdt WHERE EXISTS (SELECT c1 FROM t2 WHERE c2 > fdt.c1)
```

`fdt` is the table derived in the `FROM` clause. Rows that do not meet the search condition of the `WHERE` clause are eliminated from `fdt`. Notice the use of scalar subqueries as value expressions. Just like any other query, the subqueries can employ complex table expressions. Notice also how `fdt` is referenced in the subqueries. Qualifying `c1` as `fdt.c1` is only necessary if `c1` is also the name of a column in the derived input table of the subquery. But qualifying the column name adds clarity even when it is not needed. This example shows how the column naming scope of an outer query extends into its inner queries.

7.2.3. The `GROUP BY` and `HAVING` Clauses

After passing the `WHERE` filter, the derived input table might be subject to grouping, using the `GROUP BY` clause, and elimination of group rows using the `HAVING` clause.

```
SELECT select_list
    FROM ...
    [WHERE ...]
    GROUP BY grouping_column_reference [, grouping_column_reference]...
```

The *GROUP BY Clause* is used to group together those rows in a table that have the same values in all the columns listed. The order in which the columns are listed does not matter. The effect is to combine each set of rows having common values into one group row that represents all rows in the group. This is done to eliminate redundancy in the output and/or compute aggregates that apply to these groups. For instance:

```
=> SELECT * FROM test1;
 x | y
---+---
 a | 3
 c | 2
 b | 5
 a | 1
(4 rows)

=> SELECT x FROM test1 GROUP BY x;
 x
---
 a
 b
 c
(3 rows)
```

In the second query, we could not have written `SELECT * FROM test1 GROUP BY x`, because there is no single value for the column `y` that could be associated with each group. The grouped-by columns can be referenced in the select list since they have a single value in each group.

In general, if a table is grouped, columns that are not listed in `GROUP BY` cannot be referenced except in aggregate expressions. An example with aggregate expressions is:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x;
 x | sum
---+-----
 a |   4
```

```
 b |   5
 c |   2
(3 rows)
```

Here `sum` is an aggregate function that computes a single value over the entire group. More information about the available aggregate functions can be found in Section 9.20.

> **Tip:** Grouping without aggregate expressions effectively calculates the set of distinct values in a column. This can also be achieved using the `DISTINCT` clause (see Section 7.3.3).

Here is another example: it calculates the total sales for each product (rather than the total sales of all products):

```
SELECT product_id, p.name, (sum(s.units) * p.price) AS sales
    FROM products p LEFT JOIN sales s USING (product_id)
    GROUP BY product_id, p.name, p.price;
```

In this example, the columns `product_id`, `p.name`, and `p.price` must be in the `GROUP BY` clause since they are referenced in the query select list (but see below). The column `s.units` does not have to be in the `GROUP BY` list since it is only used in an aggregate expression (`sum(...)`), which represents the sales of a product. For each product, the query returns a summary row about all sales of the product.

If the products table is set up so that, say, `product_id` is the primary key, then it would be enough to group by `product_id` in the above example, since name and price would be *functionally dependent* on the product ID, and so there would be no ambiguity about which name and price value to return for each product ID group.

In strict SQL, `GROUP BY` can only group by columns of the source table but PostgreSQL extends this to also allow `GROUP BY` to group by columns in the select list. Grouping by value expressions instead of simple column names is also allowed.

If a table has been grouped using `GROUP BY`, but only certain groups are of interest, the `HAVING` clause can be used, much like a `WHERE` clause, to eliminate groups from the result. The syntax is:

```
SELECT select_list FROM ... [WHERE ...] GROUP BY ... HAVING boolean_expression
```

Expressions in the `HAVING` clause can refer both to grouped expressions and to ungrouped expressions (which necessarily involve an aggregate function).

Example:

```
=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING sum(y) > 3;
 x | sum
---+-----
 a |   4
 b |   5
(2 rows)

=> SELECT x, sum(y) FROM test1 GROUP BY x HAVING x < 'c';
 x | sum
---+-----
 a |   4
 b |   5
(2 rows)
```

Again, a more realistic example:

```
SELECT product_id, p.name, (sum(s.units) * (p.price - p.cost)) AS profit
    FROM products p LEFT JOIN sales s USING (product_id)
    WHERE s.date > CURRENT_DATE - INTERVAL '4 weeks'
    GROUP BY product_id, p.name, p.price, p.cost
    HAVING sum(p.price * s.units) > 5000;
```

In the example above, the `WHERE` clause is selecting rows by a column that is not grouped (the expression is only true for sales during the last four weeks), while the `HAVING` clause restricts the output to groups with total gross sales over 5000. Note that the aggregate expressions do not necessarily need to be the same in all parts of the query.

If a query contains aggregate function calls, but no `GROUP BY` clause, grouping still occurs: the result is a single group row (or perhaps no rows at all, if the single row is then eliminated by `HAVING`). The same is true if it contains a `HAVING` clause, even without any aggregate function calls or `GROUP BY` clause.

7.2.4. Window Function Processing

If the query contains any window functions (see Section 3.5, Section 9.21 and Section 4.2.8), these functions are evaluated after any grouping, aggregation, and `HAVING` filtering is performed. That is, if the query uses any aggregates, `GROUP BY`, or `HAVING`, then the rows seen by the window functions are the group rows instead of the original table rows from `FROM`/`WHERE`.

When multiple window functions are used, all the window functions having syntactically equivalent `PARTITION BY` and `ORDER BY` clauses in their window definitions are guaranteed to be evaluated in a single pass over the data. Therefore they will see the same sort ordering, even if the `ORDER BY` does not uniquely determine an ordering. However, no guarantees are made about the evaluation of functions having different `PARTITION BY` or `ORDER BY` specifications. (In such cases a sort step is typically required between the passes of window function evaluations, and the sort is not guaranteed to preserve ordering of rows that its `ORDER BY` sees as equivalent.)

Currently, window functions always require presorted data, and so the query output will be ordered according to one or another of the window functions' `PARTITION BY`/`ORDER BY` clauses. It is not recommended to rely on this, however. Use an explicit top-level `ORDER BY` clause if you want to be sure the results are sorted in a particular way.

7.3. Select Lists

As shown in the previous section, the table expression in the `SELECT` command constructs an intermediate virtual table by possibly combining tables, views, eliminating rows, grouping, etc. This table is finally passed on to processing by the *select list*. The select list determines which *columns* of the intermediate table are actually output.

7.3.1. Select-List Items

The simplest kind of select list is `*` which emits all columns that the table expression produces. Otherwise, a select list is a comma-separated list of value expressions (as defined in Section 4.2). For

instance, it could be a list of column names:

```
SELECT a, b, c FROM ...
```

The columns names a, b, and c are either the actual names of the columns of tables referenced in the FROM clause, or the aliases given to them as explained in Section 7.2.1.2. The name space available in the select list is the same as in the WHERE clause, unless grouping is used, in which case it is the same as in the HAVING clause.

If more than one table has a column of the same name, the table name must also be given, as in:

```
SELECT tbl1.a, tbl2.a, tbl1.b FROM ...
```

When working with multiple tables, it can also be useful to ask for all the columns of a particular table:

```
SELECT tbl1.*, tbl2.a FROM ...
```

(See also Section 7.2.2.)

If an arbitrary value expression is used in the select list, it conceptually adds a new virtual column to the returned table. The value expression is evaluated once for each result row, with the row's values substituted for any column references. But the expressions in the select list do not have to reference any columns in the table expression of the FROM clause; they can be constant arithmetic expressions, for instance.

7.3.2. Column Labels

The entries in the select list can be assigned names for subsequent processing, such as for use in an ORDER BY clause or for display by the client application. For example:

```
SELECT a AS value, b + c AS sum FROM ...
```

If no output column name is specified using AS, the system assigns a default column name. For simple column references, this is the name of the referenced column. For function calls, this is the name of the function. For complex expressions, the system will generate a generic name.

The AS keyword is optional, but only if the new column name does not match any PostgreSQL keyword (see Appendix C). To avoid an accidental match to a keyword, you can double-quote the column name. For example, VALUE is a keyword, so this does not work:

```
SELECT a value, b + c AS sum FROM ...
```

but this does:

```
SELECT a "value", b + c AS sum FROM ...
```

For protection against possible future keyword additions, it is recommended that you always either write AS or double-quote the output column name.

> **Note:** The naming of output columns here is different from that done in the FROM clause (see Section 7.2.1.2). It is possible to rename the same column twice, but the name assigned in the select list is the one that will be passed on.

7.3.3. DISTINCT

After the select list has been processed, the result table can optionally be subject to the elimination of duplicate rows. The DISTINCT key word is written directly after SELECT to specify this:

```
SELECT DISTINCT select_list ...
```

(Instead of DISTINCT the key word ALL can be used to specify the default behavior of retaining all rows.)

Obviously, two rows are considered distinct if they differ in at least one column value. Null values are considered equal in this comparison.

Alternatively, an arbitrary expression can determine what rows are to be considered distinct:

```
SELECT DISTINCT ON (expression [, expression ...]) select_list ...
```

Here *expression* is an arbitrary value expression that is evaluated for all rows. A set of rows for which all the expressions are equal are considered duplicates, and only the first row of the set is kept in the output. Note that the "first row" of a set is unpredictable unless the query is sorted on enough columns to guarantee a unique ordering of the rows arriving at the DISTINCT filter. (DISTINCT ON processing occurs after ORDER BY sorting.)

The DISTINCT ON clause is not part of the SQL standard and is sometimes considered bad style because of the potentially indeterminate nature of its results. With judicious use of GROUP BY and subqueries in FROM, this construct can be avoided, but it is often the most convenient alternative.

7.4. Combining Queries

The results of two queries can be combined using the set operations union, intersection, and difference. The syntax is

```
query1 UNION [ALL] query2
query1 INTERSECT [ALL] query2
query1 EXCEPT [ALL] query2
```

query1 and *query2* are queries that can use any of the features discussed up to this point. Set operations can also be nested and chained, for example

```
query1 UNION query2 UNION query3
```

which is executed as:

```
(query1 UNION query2) UNION query3
```

UNION effectively appends the result of *query2* to the result of *query1* (although there is no guarantee that this is the order in which the rows are actually returned). Furthermore, it eliminates duplicate rows from its result, in the same way as DISTINCT, unless UNION ALL is used.

INTERSECT returns all rows that are both in the result of *query1* and in the result of *query2*. Duplicate rows are eliminated unless INTERSECT ALL is used.

EXCEPT returns all rows that are in the result of *query1* but not in the result of *query2*. (This is sometimes called the *difference* between two queries.) Again, duplicates are eliminated unless EXCEPT ALL is used.

In order to calculate the union, intersection, or difference of two queries, the two queries must be "union compatible", which means that they return the same number of columns and the corresponding columns have compatible data types, as described in Section 10.5.

7.5. Sorting Rows

After a query has produced an output table (after the select list has been processed) it can optionally be sorted. If sorting is not chosen, the rows will be returned in an unspecified order. The actual order in that case will depend on the scan and join plan types and the order on disk, but it must not be relied on. A particular output ordering can only be guaranteed if the sort step is explicitly chosen.

The ORDER BY clause specifies the sort order:

```
SELECT select_list
    FROM table_expression
    ORDER BY sort_expression1 [ASC | DESC] [NULLS { FIRST | LAST }]
             [, sort_expression2 [ASC | DESC] [NULLS { FIRST | LAST }] ...]
```

The sort expression(s) can be any expression that would be valid in the query's select list. An example is:

```
SELECT a, b FROM table1 ORDER BY a + b, c;
```

When more than one expression is specified, the later values are used to sort rows that are equal according to the earlier values. Each expression can be followed by an optional ASC or DESC keyword to set the sort direction to ascending or descending. ASC order is the default. Ascending order puts smaller values first, where "smaller" is defined in terms of the < operator. Similarly, descending order is determined with the > operator. [1]

The NULLS FIRST and NULLS LAST options can be used to determine whether nulls appear before or after non-null values in the sort ordering. By default, null values sort as if larger than any non-null value; that is, NULLS FIRST is the default for DESC order, and NULLS LAST otherwise.

Note that the ordering options are considered independently for each sort column. For example ORDER BY x, y DESC means ORDER BY x ASC, y DESC, which is not the same as ORDER BY x DESC, y DESC.

A *sort_expression* can also be the column label or number of an output column, as in:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum;
SELECT a, max(b) FROM table1 GROUP BY a ORDER BY 1;
```

both of which sort by the first output column. Note that an output column name has to stand alone, that is, it cannot be used in an expression — for example, this is *not* correct:

```
SELECT a + b AS sum, c FROM table1 ORDER BY sum + c;          -- wrong
```

This restriction is made to reduce ambiguity. There is still ambiguity if an ORDER BY item is a simple name that could match either an output column name or a column from the table expression. The

1. Actually, PostgreSQL uses the *default B-tree operator class* for the expression's data type to determine the sort ordering for ASC and DESC. Conventionally, data types will be set up so that the < and > operators correspond to this sort ordering, but a user-defined data type's designer could choose to do something different.

output column is used in such cases. This would only cause confusion if you use AS to rename an output column to match some other table column's name.

ORDER BY can be applied to the result of a UNION, INTERSECT, or EXCEPT combination, but in this case it is only permitted to sort by output column names or numbers, not by expressions.

7.6. LIMIT and OFFSET

LIMIT and OFFSET allow you to retrieve just a portion of the rows that are generated by the rest of the query:

```
SELECT select_list
    FROM table_expression
    [ ORDER BY ... ]
    [ LIMIT { number | ALL } ] [ OFFSET number ]
```

If a limit count is given, no more than that many rows will be returned (but possibly less, if the query itself yields less rows). LIMIT ALL is the same as omitting the LIMIT clause.

OFFSET says to skip that many rows before beginning to return rows. OFFSET 0 is the same as omitting the OFFSET clause, and LIMIT NULL is the same as omitting the LIMIT clause. If both OFFSET and LIMIT appear, then OFFSET rows are skipped before starting to count the LIMIT rows that are returned.

When using LIMIT, it is important to use an ORDER BY clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows. You might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? The ordering is unknown, unless you specified ORDER BY.

The query optimizer takes LIMIT into account when generating query plans, so you are very likely to get different plans (yielding different row orders) depending on what you give for LIMIT and OFFSET. Thus, using different LIMIT/OFFSET values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with ORDER BY. This is not a bug; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless ORDER BY is used to constrain the order.

The rows skipped by an OFFSET clause still have to be computed inside the server; therefore a large OFFSET might be inefficient.

7.7. VALUES Lists

VALUES provides a way to generate a "constant table" that can be used in a query without having to actually create and populate a table on-disk. The syntax is

```
VALUES ( expression [, ...] ) [, ...]
```

Each parenthesized list of expressions generates a row in the table. The lists must all have the same number of elements (i.e., the number of columns in the table), and corresponding entries in each list must have compatible data types. The actual data type assigned to each column of the result is determined using the same rules as for UNION (see Section 10.5).

As an example:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

By default, PostgreSQL assigns the names `column1`, `column2`, etc. to the columns of a `VALUES` table. The column names are not specified by the SQL standard and different database systems do it differently, so it's usually better to override the default names with a table alias list, like this:

```
=> SELECT * FROM (VALUES (1, 'one'), (2, 'two'), (3, 'three')) AS t (num,letter);
 num | letter
-----+--------
   1 | one
   2 | two
   3 | three
(3 rows)
```

Syntactically, `VALUES` followed by expression lists is treated as equivalent to:

```
SELECT select_list FROM table_expression
```

and can appear anywhere a `SELECT` can. For example, you can use it as part of a `UNION`, or attach a *sort_specification* (`ORDER BY`, `LIMIT`, and/or `OFFSET`) to it. `VALUES` is most commonly used as the data source in an `INSERT` command, and next most commonly as a subquery.

For more information see VALUES.

7.8. `WITH` Queries (Common Table Expressions)

`WITH` provides a way to write auxiliary statements for use in a larger query. These statements, which are often referred to as Common Table Expressions or CTEs, can be thought of as defining temporary tables that exist just for one query. Each auxiliary statement in a `WITH` clause can be a `SELECT`, `INSERT`, `UPDATE`, or `DELETE`; and the `WITH` clause itself is attached to a primary statement that can also be a `SELECT`, `INSERT`, `UPDATE`, or `DELETE`.

7.8.1. `SELECT` in `WITH`

The basic value of `SELECT` in `WITH` is to break down complicated queries into simpler parts. An example is:

```
WITH regional_sales AS (
        SELECT region, SUM(amount) AS total_sales
        FROM orders
        GROUP BY region
     ), top_regions AS (
        SELECT region
        FROM regional_sales
        WHERE total_sales > (SELECT SUM(total_sales)/10 FROM regional_sales)
```

```
    )
SELECT region,
       product,
       SUM(quantity) AS product_units,
       SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```

which displays per-product sales totals in only the top sales regions. The `WITH` clause defines two auxiliary statements named `regional_sales` and `top_regions`, where the output of `regional_sales` is used in `top_regions` and the output of `top_regions` is used in the primary `SELECT` query. This example could have been written without `WITH`, but we'd have needed two levels of nested sub-`SELECT`s. It's a bit easier to follow this way.

The optional `RECURSIVE` modifier changes `WITH` from a mere syntactic convenience into a feature that accomplishes things not otherwise possible in standard SQL. Using `RECURSIVE`, a `WITH` query can refer to its own output. A very simple example is this query to sum the integers from 1 through 100:

```
WITH RECURSIVE t(n) AS (
    VALUES (1)
  UNION ALL
    SELECT n+1 FROM t WHERE n < 100
)
SELECT sum(n) FROM t;
```

The general form of a recursive `WITH` query is always a *non-recursive term*, then `UNION` (or `UNION ALL`), then a *recursive term*, where only the recursive term can contain a reference to the query's own output. Such a query is executed as follows:

Recursive Query Evaluation

1. Evaluate the non-recursive term. For `UNION` (but not `UNION ALL`), discard duplicate rows. Include all remaining rows in the result of the recursive query, and also place them in a temporary *working table*.
2. So long as the working table is not empty, repeat these steps:
    a. Evaluate the recursive term, substituting the current contents of the working table for the recursive self-reference. For `UNION` (but not `UNION ALL`), discard duplicate rows and rows that duplicate any previous result row. Include all remaining rows in the result of the recursive query, and also place them in a temporary *intermediate table*.
    b. Replace the contents of the working table with the contents of the intermediate table, then empty the intermediate table.

> **Note:** Strictly speaking, this process is iteration not recursion, but `RECURSIVE` is the terminology chosen by the SQL standards committee.

In the example above, the working table has just a single row in each step, and it takes on the values from 1 through 100 in successive steps. In the 100th step, there is no output because of the `WHERE` clause, and so the query terminates.

Recursive queries are typically used to deal with hierarchical or tree-structured data. A useful example is this query to find all the direct and indirect sub-parts of a product, given only a table that shows immediate inclusions:

```
WITH RECURSIVE included_parts(sub_part, part, quantity) AS (
    SELECT sub_part, part, quantity FROM parts WHERE part = 'our_product'
  UNION ALL
    SELECT p.sub_part, p.part, p.quantity
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
  )
SELECT sub_part, SUM(quantity) as total_quantity
FROM included_parts
GROUP BY sub_part
```

When working with recursive queries it is important to be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. Sometimes, using `UNION` instead of `UNION ALL` can accomplish this by discarding rows that duplicate previous output rows. However, often a cycle does not involve output rows that are completely duplicate: it may be necessary to check just one or a few fields to see if the same point has been reached before. The standard method for handling such situations is to compute an array of the already-visited values. For example, consider the following query that searches a table `graph` using a `link` field:

```
WITH RECURSIVE search_graph(id, link, data, depth) AS (
        SELECT g.id, g.link, g.data, 1
        FROM graph g
      UNION ALL
        SELECT g.id, g.link, g.data, sg.depth + 1
        FROM graph g, search_graph sg
        WHERE g.id = sg.link
)
SELECT * FROM search_graph;
```

This query will loop if the `link` relationships contain cycles. Because we require a "depth" output, just changing `UNION ALL` to `UNION` would not eliminate the looping. Instead we need to recognize whether we have reached the same row again while following a particular path of links. We add two columns `path` and `cycle` to the loop-prone query:

```
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (
        SELECT g.id, g.link, g.data, 1,
          ARRAY[g.id],
          false
        FROM graph g
      UNION ALL
        SELECT g.id, g.link, g.data, sg.depth + 1,
          path || g.id,
          g.id = ANY(path)
        FROM graph g, search_graph sg
        WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;
```

Aside from preventing cycles, the array value is often useful in its own right as representing the "path" taken to reach any particular row.

In the general case where more than one field needs to be checked to recognize a cycle, use an array of rows. For example, if we needed to compare fields `f1` and `f2`:

```
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (
        SELECT g.id, g.link, g.data, 1,
          ARRAY[ROW(g.f1, g.f2)],
          false
        FROM graph g
      UNION ALL
        SELECT g.id, g.link, g.data, sg.depth + 1,
          path || ROW(g.f1, g.f2),
          ROW(g.f1, g.f2) = ANY(path)
        FROM graph g, search_graph sg
        WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;
```

Tip: Omit the `ROW()` syntax in the common case where only one field needs to be checked to recognize a cycle. This allows a simple array rather than a composite-type array to be used, gaining efficiency.

Tip: The recursive query evaluation algorithm produces its output in breadth-first search order. You can display the results in depth-first search order by making the outer query `ORDER BY` a "path" column constructed in this way.

A helpful trick for testing queries when you are not certain if they might loop is to place a `LIMIT` in the parent query. For example, this query would loop forever without the `LIMIT`:

```
WITH RECURSIVE t(n) AS (
    SELECT 1
  UNION ALL
    SELECT n+1 FROM t
)
SELECT n FROM t LIMIT 100;
```

This works because PostgreSQL's implementation evaluates only as many rows of a `WITH` query as are actually fetched by the parent query. Using this trick in production is not recommended, because other systems might work differently. Also, it usually won't work if you make the outer query sort the recursive query's results or join them to some other table, because in such cases the outer query will usually try to fetch all of the `WITH` query's output anyway.

A useful property of `WITH` queries is that they are evaluated only once per execution of the parent query, even if they are referred to more than once by the parent query or sibling `WITH` queries. Thus, expensive calculations that are needed in multiple places can be placed within a `WITH` query to avoid redundant work. Another possible application is to prevent unwanted multiple evaluations of functions with side-effects. However, the other side of this coin is that the optimizer is less able to push restrictions from the parent query down into a `WITH` query than an ordinary sub-query. The `WITH` query will generally be evaluated as written, without suppression of rows that the parent query might discard afterwards. (But, as mentioned above, evaluation might stop early if the reference(s) to the query demand only a limited number of rows.)

The examples above only show WITH being used with SELECT, but it can be attached in the same way to INSERT, UPDATE, or DELETE. In each case it effectively provides temporary table(s) that can be referred to in the main command.

7.8.2. Data-Modifying Statements in WITH

You can use data-modifying statements (INSERT, UPDATE, or DELETE) in WITH. This allows you to perform several different operations in the same query. An example is:

```
WITH moved_rows AS (
    DELETE FROM products
    WHERE
        "date" >= '2010-10-01' AND
        "date" < '2010-11-01'
    RETURNING *
)
INSERT INTO products_log
SELECT * FROM moved_rows;
```

This query effectively moves rows from products to products_log. The DELETE in WITH deletes the specified rows from products, returning their contents by means of its RETURNING clause; and then the primary query reads that output and inserts it into products_log.

A fine point of the above example is that the WITH clause is attached to the INSERT, not the sub-SELECT within the INSERT. This is necessary because data-modifying statements are only allowed in WITH clauses that are attached to the top-level statement. However, normal WITH visibility rules apply, so it is possible to refer to the WITH statement's output from the sub-SELECT.

Data-modifying statements in WITH usually have RETURNING clauses, as seen in the example above. It is the output of the RETURNING clause, *not* the target table of the data-modifying statement, that forms the temporary table that can be referred to by the rest of the query. If a data-modifying statement in WITH lacks a RETURNING clause, then it forms no temporary table and cannot be referred to in the rest of the query. Such a statement will be executed nonetheless. A not-particularly-useful example is:

```
WITH t AS (
    DELETE FROM foo
)
DELETE FROM bar;
```

This example would remove all rows from tables foo and bar. The number of affected rows reported to the client would only include rows removed from bar.

Recursive self-references in data-modifying statements are not allowed. In some cases it is possible to work around this limitation by referring to the output of a recursive WITH, for example:

```
WITH RECURSIVE included_parts(sub_part, part) AS (
    SELECT sub_part, part FROM parts WHERE part = 'our_product'
  UNION ALL
    SELECT p.sub_part, p.part
    FROM included_parts pr, parts p
    WHERE p.part = pr.sub_part
  )
DELETE FROM parts
  WHERE part IN (SELECT part FROM included_parts);
```

This query would remove all direct and indirect subparts of a product.

Data-modifying statements in WITH are executed exactly once, and always to completion, independently of whether the primary query reads all (or indeed any) of their output. Notice that this is different from the rule for SELECT in WITH: as stated in the previous section, execution of a SELECT is carried only as far as the primary query demands its output.

The sub-statements in WITH are executed concurrently with each other and with the main query. Therefore, when using data-modifying statements in WITH, the order in which the specified updates actually happen is unpredictable. All the statements are executed with the same *snapshot* (see Chapter 13), so they cannot "see" one another's effects on the target tables. This alleviates the effects of the unpredictability of the actual order of row updates, and means that RETURNING data is the only way to communicate changes between different WITH sub-statements and the main query. An example of this is that in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM products;
```

the outer SELECT would return the original prices before the action of the UPDATE, while in

```
WITH t AS (
    UPDATE products SET price = price * 1.05
    RETURNING *
)
SELECT * FROM t;
```

the outer SELECT would return the updated data.

Trying to update the same row twice in a single statement is not supported. Only one of the modifications takes place, but it is not easy (and sometimes not possible) to reliably predict which one. This also applies to deleting a row that was already updated in the same statement: only the update is performed. Therefore you should generally avoid trying to modify a single row twice in a single statement. In particular avoid writing WITH sub-statements that could affect the same rows changed by the main statement or a sibling sub-statement. The effects of such a statement will not be predictable.

At present, any table used as the target of a data-modifying statement in WITH must not have a conditional rule, nor an ALSO rule, nor an INSTEAD rule that expands to multiple statements.

Chapter 8. Data Types

PostgreSQL has a rich set of native data types available to users. Users can add new types to PostgreSQL using the CREATE TYPE command.

Table 8-1 shows all the built-in general-purpose data types. Most of the alternative names listed in the "Aliases" column are the names used internally by PostgreSQL for historical reasons. In addition, some internally used or deprecated types are available, but are not listed here.

Table 8-1. Data Types

Name	Aliases	Description
bigint	int8	signed eight-byte integer
bigserial	serial8	autoincrementing eight-byte integer
bit [(*n*)]		fixed-length bit string
bit varying [(*n*)]	varbit	variable-length bit string
boolean	bool	logical Boolean (true/false)
box		rectangular box on a plane
bytea		binary data ("byte array")
character [(*n*)]	char [(*n*)]	fixed-length character string
character varying [(*n*)]	varchar [(*n*)]	variable-length character string
cidr		IPv4 or IPv6 network address
circle		circle on a plane
date		calendar date (year, month, day)
double precision	float8	double precision floating-point number (8 bytes)
inet		IPv4 or IPv6 host address
integer	int, int4	signed four-byte integer
interval [*fields*] [(*p*)]		time span
json		textual JSON data
jsonb		binary JSON data, decomposed
line		infinite line on a plane
lseg		line segment on a plane
macaddr		MAC (Media Access Control) address
money		currency amount
numeric [(*p*, *s*)]	decimal [(*p*, *s*)]	exact numeric of selectable precision
path		geometric path on a plane
pg_lsn		PostgreSQL Log Sequence Number
point		geometric point on a plane

Name	Aliases	Description
polygon		closed geometric path on a plane
real	float4	single precision floating-point number (4 bytes)
smallint	int2	signed two-byte integer
smallserial	serial2	autoincrementing two-byte integer
serial	serial4	autoincrementing four-byte integer
text		variable-length character string
time [(*p*)] [without time zone]		time of day (no time zone)
time [(*p*)] with time zone	timetz	time of day, including time zone
timestamp [(*p*)] [without time zone]		date and time (no time zone)
timestamp [(*p*)] with time zone	timestamptz	date and time, including time zone
tsquery		text search query
tsvector		text search document
txid_snapshot		user-level transaction ID snapshot
uuid		universally unique identifier
xml		XML data

Compatibility: The following types (or spellings thereof) are specified by SQL: bigint, bit, bit varying, boolean, char, character varying, character, varchar, date, double precision, integer, interval, numeric, decimal, real, smallint, time (with or without time zone), timestamp (with or without time zone), xml.

Each data type has an external representation determined by its input and output functions. Many of the built-in types have obvious external formats. However, several types are either unique to PostgreSQL, such as geometric paths, or have several possible formats, such as the date and time types. Some of the input and output functions are not invertible, i.e., the result of an output function might lose accuracy when compared to the original input.

8.1. Numeric Types

Numeric types consist of two-, four-, and eight-byte integers, four- and eight-byte floating-point numbers, and selectable-precision decimals. Table 8-2 lists the available types.

Table 8-2. Numeric Types

Name	Storage Size	Description	Range

Name	Storage Size	Description	Range
`smallint`	2 bytes	small-range integer	-32768 to +32767
`integer`	4 bytes	typical choice for integer	-2147483648 to +2147483647
`bigint`	8 bytes	large-range integer	-9223372036854775808 to +9223372036854775807
`decimal`	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
`numeric`	variable	user-specified precision, exact	up to 131072 digits before the decimal point; up to 16383 digits after the decimal point
`real`	4 bytes	variable-precision, inexact	6 decimal digits precision
`double precision`	8 bytes	variable-precision, inexact	15 decimal digits precision
`smallserial`	2 bytes	small autoincrementing integer	1 to 32767
`serial`	4 bytes	autoincrementing integer	1 to 2147483647
`bigserial`	8 bytes	large autoincrementing integer	1 to 9223372036854775807

The syntax of constants for the numeric types is described in Section 4.1.2. The numeric types have a full set of corresponding arithmetic operators and functions. Refer to Chapter 9 for more information. The following sections describe the types in detail.

8.1.1. Integer Types

The types `smallint`, `integer`, and `bigint` store whole numbers, that is, numbers without fractional components, of various ranges. Attempts to store values outside of the allowed range will result in an error.

The type `integer` is the common choice, as it offers the best balance between range, storage size, and performance. The `smallint` type is generally only used if disk space is at a premium. The `bigint` type is designed to be used when the range of the `integer` type is insufficient.

SQL only specifies the integer types `integer` (or `int`), `smallint`, and `bigint`. The type names `int2`, `int4`, and `int8` are extensions, which are also used by some other SQL database systems.

8.1.2. Arbitrary Precision Numbers

The type `numeric` can store numbers with a very large number of digits and perform calculations exactly. It is especially recommended for storing monetary amounts and other quantities where exactness is required. However, arithmetic on `numeric` values is very slow compared to the integer types, or to the floating-point types described in the next section.

We use the following terms below: The *scale* of a `numeric` is the count of decimal digits in the fractional part, to the right of the decimal point. The *precision* of a `numeric` is the total count of significant digits in the whole number, that is, the number of digits to both sides of the decimal point. So the number 23.5141 has a precision of 6 and a scale of 4. Integers can be considered to have a scale of zero.

Both the maximum precision and the maximum scale of a `numeric` column can be configured. To declare a column of type `numeric` use the syntax:

```
NUMERIC(precision, scale)
```

The precision must be positive, the scale zero or positive. Alternatively:

```
NUMERIC(precision)
```

selects a scale of 0. Specifying:

```
NUMERIC
```

without any precision or scale creates a column in which numeric values of any precision and scale can be stored, up to the implementation limit on precision. A column of this kind will not coerce input values to any particular scale, whereas `numeric` columns with a declared scale will coerce input values to that scale. (The SQL standard requires a default scale of 0, i.e., coercion to integer precision. We find this a bit useless. If you're concerned about portability, always specify the precision and scale explicitly.)

> **Note:** The maximum allowed precision when explicitly specified in the type declaration is 1000; `NUMERIC` without a specified precision is subject to the limits described in Table 8-2.

If the scale of a value to be stored is greater than the declared scale of the column, the system will round the value to the specified number of fractional digits. Then, if the number of digits to the left of the decimal point exceeds the declared precision minus the declared scale, an error is raised.

Numeric values are physically stored without any extra leading or trailing zeroes. Thus, the declared precision and scale of a column are maximums, not fixed allocations. (In this sense the `numeric` type is more akin to `varchar(n)` than to `char(n)`.) The actual storage requirement is two bytes for each group of four decimal digits, plus three to eight bytes overhead.

In addition to ordinary numeric values, the `numeric` type allows the special value `NaN`, meaning "not-a-number". Any operation on `NaN` yields another `NaN`. When writing this value as a constant in an SQL command, you must put quotes around it, for example `UPDATE table SET x = 'NaN'`. On input, the string `NaN` is recognized in a case-insensitive manner.

> **Note:** In most implementations of the "not-a-number" concept, `NaN` is not considered equal to any other numeric value (including `NaN`). In order to allow `numeric` values to be sorted and used in tree-based indexes, PostgreSQL treats `NaN` values as equal, and greater than all non-`NaN` values.

The types `decimal` and `numeric` are equivalent. Both types are part of the SQL standard.

8.1.3. Floating-Point Types

The data types `real` and `double precision` are inexact, variable-precision numeric types. In practice, these types are usually implementations of IEEE Standard 754 for Binary Floating-Point Arithmetic (single and double precision, respectively), to the extent that the underlying processor, operating system, and compiler support it.

Inexact means that some values cannot be converted exactly to the internal format and are stored as approximations, so that storing and retrieving a value might show slight discrepancies. Managing these errors and how they propagate through calculations is the subject of an entire branch of mathematics and computer science and will not be discussed here, except for the following points:

- If you require exact storage and calculations (such as for monetary amounts), use the `numeric` type instead.
- If you want to do complicated calculations with these types for anything important, especially if you rely on certain behavior in boundary cases (infinity, underflow), you should evaluate the implementation carefully.
- Comparing two floating-point values for equality might not always work as expected.

On most platforms, the `real` type has a range of at least 1E-37 to 1E+37 with a precision of at least 6 decimal digits. The `double precision` type typically has a range of around 1E-307 to 1E+308 with a precision of at least 15 digits. Values that are too large or too small will cause an error. Rounding might take place if the precision of an input number is too high. Numbers too close to zero that are not representable as distinct from zero will cause an underflow error.

> **Note:** The extra_float_digits setting controls the number of extra significant digits included when a floating point value is converted to text for output. With the default value of `0`, the output is the same on every platform supported by PostgreSQL. Increasing it will produce output that more accurately represents the stored value, but may be unportable.

In addition to ordinary numeric values, the floating-point types have several special values:

```
Infinity
-Infinity
NaN
```

These represent the IEEE 754 special values “infinity”, “negative infinity”, and “not-a-number”, respectively. (On a machine whose floating-point arithmetic does not follow IEEE 754, these values will probably not work as expected.) When writing these values as constants in an SQL command, you must put quotes around them, for example `UPDATE table SET x = 'Infinity'`. On input, these strings are recognized in a case-insensitive manner.

> **Note:** IEEE754 specifies that `NaN` should not compare equal to any other floating-point value (including `NaN`). In order to allow floating-point values to be sorted and used in tree-based indexes, PostgreSQL treats `NaN` values as equal, and greater than all non-`NaN` values.

PostgreSQL also supports the SQL-standard notations `float` and `float(p)` for specifying inexact numeric types. Here, *p* specifies the minimum acceptable precision in *binary* digits. PostgreSQL accepts `float(1)` to `float(24)` as selecting the `real` type, while `float(25)` to `float(53)` select `double precision`. Values of *p* outside the allowed range draw an error. `float` with no precision specified is taken to mean `double precision`.

> **Note:** The assumption that `real` and `double precision` have exactly 24 and 53 bits in the mantissa respectively is correct for IEEE-standard floating point implementations. On non-IEEE platforms it might be off a little, but for simplicity the same ranges of *p* are used on all platforms.

8.1.4. Serial Types

The data types `smallserial`, `serial` and `bigserial` are not true types, but merely a notational convenience for creating unique identifier columns (similar to the `AUTO_INCREMENT` property supported by some other databases). In the current implementation, specifying:

```
CREATE TABLE tablename (
    colname SERIAL
);
```

is equivalent to specifying:

```
CREATE SEQUENCE tablename_colname_seq;
CREATE TABLE tablename (
    colname integer NOT NULL DEFAULT nextval('tablename_colname_seq')
);
ALTER SEQUENCE tablename_colname_seq OWNED BY tablename.colname;
```

Thus, we have created an integer column and arranged for its default values to be assigned from a sequence generator. A `NOT NULL` constraint is applied to ensure that a null value cannot be inserted. (In most cases you would also want to attach a `UNIQUE` or `PRIMARY KEY` constraint to prevent duplicate values from being inserted by accident, but this is not automatic.) Lastly, the sequence is marked as "owned by" the column, so that it will be dropped if the column or table is dropped.

> **Note:** Because `smallserial`, `serial` and `bigserial` are implemented using sequences, there may be "holes" or gaps in the sequence of values which appears in the column, even if no rows are ever deleted. A value allocated from the sequence is still "used up" even if a row containing that value is never successfully inserted into the table column. This may happen, for example, if the inserting transaction rolls back. See `nextval()` in Section 9.16 for details.

To insert the next value of the sequence into the `serial` column, specify that the `serial` column should be assigned its default value. This can be done either by excluding the column from the list of columns in the `INSERT` statement, or through the use of the `DEFAULT` key word.

The type names `serial` and `serial4` are equivalent: both create `integer` columns. The type names `bigserial` and `serial8` work the same way, except that they create a `bigint` column. `bigserial` should be used if you anticipate the use of more than 2^{31} identifiers over the lifetime of the table. The type names `smallserial` and `serial2` also work the same way, except that they create a `smallint` column.

The sequence created for a `serial` column is automatically dropped when the owning column is dropped. You can drop the sequence without dropping the column, but this will force removal of the column default expression.

8.2. Monetary Types

The `money` type stores a currency amount with a fixed fractional precision; see Table 8-3. The fractional precision is determined by the database's lc_monetary setting. The range shown in the table assumes there are two fractional digits. Input is accepted in a variety of formats, including integer and floating-point literals, as well as typical currency formatting, such as `'$1,000.00'`. Output is generally in the latter form but depends on the locale.

Table 8-3. Monetary Types

Name	Storage Size	Description	Range
money	8 bytes	currency amount	-92233720368547758.08 to +92233720368547758.07

Since the output of this data type is locale-sensitive, it might not work to load `money` data into a database that has a different setting of `lc_monetary`. To avoid problems, before restoring a dump into a new database make sure `lc_monetary` has the same or equivalent value as in the database that was dumped.

Values of the `numeric`, `int`, and `bigint` data types can be cast to `money`. Conversion from the `real` and `double precision` data types can be done by casting to `numeric` first, for example:

```
SELECT '12.34'::float8::numeric::money;
```

However, this is not recommended. Floating point numbers should not be used to handle money due to the potential for rounding errors.

A `money` value can be cast to `numeric` without loss of precision. Conversion to other types could potentially lose precision, and must also be done in two stages:

```
SELECT '52093.89'::money::numeric::float8;
```

When a `money` value is divided by another `money` value, the result is `double precision` (i.e., a pure number, not money); the currency units cancel each other out in the division.

8.3. Character Types

Table 8-4. Character Types

Name	Description
`character varying(`*n*`)`, `varchar(`*n*`)`	variable-length with limit

Name	Description
character(n), char(n)	fixed-length, blank padded
text	variable unlimited length

Table 8-4 shows the general-purpose character types available in PostgreSQL.

SQL defines two primary character types: character varying(n) and character(n), where n is a positive integer. Both of these types can store strings up to n characters (not bytes) in length. An attempt to store a longer string into a column of these types will result in an error, unless the excess characters are all spaces, in which case the string will be truncated to the maximum length. (This somewhat bizarre exception is required by the SQL standard.) If the string to be stored is shorter than the declared length, values of type character will be space-padded; values of type character varying will simply store the shorter string.

If one explicitly casts a value to character varying(n) or character(n), then an over-length value will be truncated to n characters without raising an error. (This too is required by the SQL standard.)

The notations varchar(n) and char(n) are aliases for character varying(n) and character(n), respectively. character without length specifier is equivalent to character(1). If character varying is used without length specifier, the type accepts strings of any size. The latter is a PostgreSQL extension.

In addition, PostgreSQL provides the text type, which stores strings of any length. Although the type text is not in the SQL standard, several other SQL database management systems have it as well.

Values of type character are physically padded with spaces to the specified width n, and are stored and displayed that way. However, trailing spaces are treated as semantically insignificant and disregarded when comparing two values of type character. In collations where whitespace is significant, this behavior can produce unexpected results, e.g. SELECT 'a '::CHAR(2) collate "C" < 'a\n'::CHAR(2) returns true. Trailing spaces are removed when converting a character value to one of the other string types. Note that trailing spaces *are* semantically significant in character varying and text values, and when using pattern matching, e.g. LIKE, regular expressions.

The storage requirement for a short string (up to 126 bytes) is 1 byte plus the actual string, which includes the space padding in the case of character. Longer strings have 4 bytes of overhead instead of 1. Long strings are compressed by the system automatically, so the physical requirement on disk might be less. Very long values are also stored in background tables so that they do not interfere with rapid access to shorter column values. In any case, the longest possible character string that can be stored is about 1 GB. (The maximum value that will be allowed for n in the data type declaration is less than that. It wouldn't be useful to change this because with multibyte character encodings the number of characters and bytes can be quite different. If you desire to store long strings with no specific upper limit, use text or character varying without a length specifier, rather than making up an arbitrary length limit.)

> **Tip:** There is no performance difference among these three types, apart from increased storage space when using the blank-padded type, and a few extra CPU cycles to check the length when storing into a length-constrained column. While character(n) has performance advantages in some other database systems, there is no such advantage in PostgreSQL; in fact character(n) is usually the slowest of the three because of its additional storage costs. In most situations text or character varying should be used instead.

Refer to Section 4.1.2.1 for information about the syntax of string literals, and to Chapter 9 for information about available operators and functions. The database character set determines the character set used to store textual values; for more information on character set support, refer to Section 22.3.

Example 8-1. Using the Character Types

```
CREATE TABLE test1 (a character(4));
INSERT INTO test1 VALUES ('ok');
SELECT a, char_length(a) FROM test1; -- ❶
  a   | char_length
------+-------------
 ok   |           2

CREATE TABLE test2 (b varchar(5));
INSERT INTO test2 VALUES ('ok');
INSERT INTO test2 VALUES ('good      ');
INSERT INTO test2 VALUES ('too long');
ERROR:  value too long for type character varying(5)
INSERT INTO test2 VALUES ('too long'::varchar(5)); -- explicit truncation
SELECT b, char_length(b) FROM test2;
   b   | char_length
-------+-------------
 ok    |           2
 good  |           5
 too l |           5
```

❶ The `char_length` function is discussed in Section 9.4.

There are two other fixed-length character types in PostgreSQL, shown in Table 8-5. The `name` type exists *only* for the storage of identifiers in the internal system catalogs and is not intended for use by the general user. Its length is currently defined as 64 bytes (63 usable characters plus terminator) but should be referenced using the constant `NAMEDATALEN` in `C` source code. The length is set at compile time (and is therefore adjustable for special uses); the default maximum length might change in a future release. The type `"char"` (note the quotes) is different from `char(1)` in that it only uses one byte of storage. It is internally used in the system catalogs as a simplistic enumeration type.

Table 8-5. Special Character Types

Name	Storage Size	Description
`"char"`	1 byte	single-byte internal type
`name`	64 bytes	internal type for object names

8.4. Binary Data Types

The `bytea` data type allows storage of binary strings; see Table 8-6.

Table 8-6. Binary Data Types

Name	Storage Size	Description

Name	Storage Size	Description
bytea	1 or 4 bytes plus the actual binary string	variable-length binary string

A binary string is a sequence of octets (or bytes). Binary strings are distinguished from character strings in two ways. First, binary strings specifically allow storing octets of value zero and other "non-printable" octets (usually, octets outside the range 32 to 126). Character strings disallow zero octets, and also disallow any other octet values and sequences of octet values that are invalid according to the database's selected character set encoding. Second, operations on binary strings process the actual bytes, whereas the processing of character strings depends on locale settings. In short, binary strings are appropriate for storing data that the programmer thinks of as "raw bytes", whereas character strings are appropriate for storing text.

The bytea type supports two external formats for input and output: PostgreSQL's historical "escape" format, and "hex" format. Both of these are always accepted on input. The output format depends on the configuration parameter bytea_output; the default is hex. (Note that the hex format was introduced in PostgreSQL 9.0; earlier versions and some tools don't understand it.)

The SQL standard defines a different binary string type, called BLOB or BINARY LARGE OBJECT. The input format is different from bytea, but the provided functions and operators are mostly the same.

8.4.1. bytea Hex Format

The "hex" format encodes binary data as 2 hexadecimal digits per byte, most significant nibble first. The entire string is preceded by the sequence \x (to distinguish it from the escape format). In some contexts, the initial backslash may need to be escaped by doubling it, in the same cases in which backslashes have to be doubled in escape format; details appear below. The hexadecimal digits can be either upper or lower case, and whitespace is permitted between digit pairs (but not within a digit pair nor in the starting \x sequence). The hex format is compatible with a wide range of external applications and protocols, and it tends to be faster to convert than the escape format, so its use is preferred.

Example:

```
SELECT E'\\xDEADBEEF';
```

8.4.2. bytea Escape Format

The "escape" format is the traditional PostgreSQL format for the bytea type. It takes the approach of representing a binary string as a sequence of ASCII characters, while converting those bytes that cannot be represented as an ASCII character into special escape sequences. If, from the point of view of the application, representing bytes as characters makes sense, then this representation can be convenient. But in practice it is usually confusing because it fuzzes up the distinction between binary strings and character strings, and also the particular escape mechanism that was chosen is somewhat unwieldy. So this format should probably be avoided for most new applications.

When entering bytea values in escape format, octets of certain values *must* be escaped, while all octet values *can* be escaped. In general, to escape an octet, convert it into its three-digit octal value and precede it by a backslash (or two backslashes, if writing the value as a literal using escape string syntax). Backslash itself (octet value 92) can alternatively be represented by double backslashes.

Table 8-7 shows the characters that must be escaped, and gives the alternative escape sequences where applicable.

Table 8-7. `bytea` Literal Escaped Octets

Decimal Octet Value	Description	Escaped Input Representation	Example	Output Representation
0	zero octet	`E'\\000'`	`SELECT E'\\000'::bytea;`	`\000`
39	single quote	`''` or `E'\\047'`	`SELECT E'\''::bytea;`	`'`
92	backslash	`E'\\\\'` or `E'\\134'`	`SELECT E'\\\\'::bytea;`	`\\`
0 to 31 and 127 to 255	"non-printable" octets	`E'\\`*xxx*`'` (octal value)	`SELECT E'\\001'::bytea;`	`\001`

The requirement to escape *non-printable* octets varies depending on locale settings. In some instances you can get away with leaving them unescaped. Note that the result in each of the examples in Table 8-7 was exactly one octet in length, even though the output representation is sometimes more than one character.

The reason multiple backslashes are required, as shown in Table 8-7, is that an input string written as a string literal must pass through two parse phases in the PostgreSQL server. The first backslash of each pair is interpreted as an escape character by the string-literal parser (assuming escape string syntax is used) and is therefore consumed, leaving the second backslash of the pair. (Dollar-quoted strings can be used to avoid this level of escaping.) The remaining backslash is then recognized by the `bytea` input function as starting either a three digit octal value or escaping another backslash. For example, a string literal passed to the server as `E'\\001'` becomes `\001` after passing through the escape string parser. The `\001` is then sent to the `bytea` input function, where it is converted to a single octet with a decimal value of 1. Note that the single-quote character is not treated specially by `bytea`, so it follows the normal rules for string literals. (See also Section 4.1.2.1.)

`Bytea` octets are sometimes escaped when output. In general, each "non-printable" octet is converted into its equivalent three-digit octal value and preceded by one backslash. Most "printable" octets are represented by their standard representation in the client character set. The octet with decimal value 92 (backslash) is doubled in the output. Details are in Table 8-8.

Table 8-8. `bytea` Output Escaped Octets

Decimal Octet Value	Description	Escaped Output Representation	Example	Output Result
92	backslash	`\\`	`SELECT E'\\134'::bytea;`	`\\`

Decimal Octet Value	Description	Escaped Output Representation	Example	Output Result
0 to 31 and 127 to 255	“non-printable” octets	`\xxx` (octal value)	`SELECT E'\\001'::bytea;`	`\001`
32 to 126	“printable” octets	client character set representation	`SELECT E'\\176'::bytea;`	~

Depending on the front end to PostgreSQL you use, you might have additional work to do in terms of escaping and unescaping `bytea` strings. For example, you might also have to escape line feeds and carriage returns if your interface automatically translates these.

8.5. Date/Time Types

PostgreSQL supports the full set of SQL date and time types, shown in Table 8-9. The operations available on these data types are described in Section 9.9. Dates are counted according to the Gregorian calendar, even in years before that calendar was introduced (see Section B.4 for more information).

Table 8-9. Date/Time Types

Name	Storage Size	Description	Low Value	High Value	Resolution
`timestamp [ (p) ] [ without time zone ]`	8 bytes	both date and time (no time zone)	4713 BC	294276 AD	1 microsecond / 14 digits
`timestamp [ (p) ] with time zone`	8 bytes	both date and time, with time zone	4713 BC	294276 AD	1 microsecond / 14 digits
`date`	4 bytes	date (no time of day)	4713 BC	5874897 AD	1 day
`time [ (p) ] [ without time zone ]`	8 bytes	time of day (no date)	00:00:00	24:00:00	1 microsecond / 14 digits
`time [ (p) ] with time zone`	12 bytes	times of day only, with time zone	00:00:00+1459	24:00:00-1459	1 microsecond / 14 digits
`interval [ fields ] [ (p) ]`	16 bytes	time interval	-178000000 years	178000000 years	1 microsecond / 14 digits

Note: The SQL standard requires that writing just `timestamp` be equivalent to `timestamp without time zone`, and PostgreSQL honors that behavior. `timestamptz` is accepted as an

abbreviation for `timestamp with time zone`; this is a PostgreSQL extension.

`time`, `timestamp`, and `interval` accept an optional precision value *p* which specifies the number of fractional digits retained in the seconds field. By default, there is no explicit bound on precision. The allowed range of *p* is from 0 to 6 for the `timestamp` and `interval` types.

Note: When `timestamp` values are stored as eight-byte integers (currently the default), microsecond precision is available over the full range of values. When `timestamp` values are stored as double precision floating-point numbers instead (a deprecated compile-time option), the effective limit of precision might be less than 6. `timestamp` values are stored as seconds before or after midnight 2000-01-01. When `timestamp` values are implemented using floating-point numbers, microsecond precision is achieved for dates within a few years of 2000-01-01, but the precision degrades for dates further away. Note that using floating-point datetimes allows a larger range of `timestamp` values to be represented than shown above: from 4713 BC up to 5874897 AD.

The same compile-time option also determines whether `time` and `interval` values are stored as floating-point numbers or eight-byte integers. In the floating-point case, large `interval` values degrade in precision as the size of the interval increases.

For the `time` types, the allowed range of *p* is from 0 to 6 when eight-byte integer storage is used, or from 0 to 10 when floating-point storage is used.

The `interval` type has an additional option, which is to restrict the set of stored fields by writing one of these phrases:

```
YEAR
MONTH
DAY
HOUR
MINUTE
SECOND
YEAR TO MONTH
DAY TO HOUR
DAY TO MINUTE
DAY TO SECOND
HOUR TO MINUTE
HOUR TO SECOND
MINUTE TO SECOND
```

Note that if both *fields* and *p* are specified, the *fields* must include `SECOND`, since the precision applies only to the seconds.

The type `time with time zone` is defined by the SQL standard, but the definition exhibits properties which lead to questionable usefulness. In most cases, a combination of `date`, `time`, `timestamp without time zone`, and `timestamp with time zone` should provide a complete range of date/time functionality required by any application.

The types `abstime` and `reltime` are lower precision types which are used internally. You are discouraged from using these types in applications; these internal types might disappear in a future release.

8.5.1. Date/Time Input

Date and time input is accepted in almost any reasonable format, including ISO 8601, SQL-compatible, traditional POSTGRES, and others. For some formats, ordering of day, month, and year in date input is ambiguous and there is support for specifying the expected ordering of these fields. Set the DateStyle parameter to `MDY` to select month-day-year interpretation, `DMY` to select day-month-year interpretation, or `YMD` to select year-month-day interpretation.

PostgreSQL is more flexible in handling date/time input than the SQL standard requires. See Appendix B for the exact parsing rules of date/time input and for the recognized text fields including months, days of the week, and time zones.

Remember that any date or time literal input needs to be enclosed in single quotes, like text strings. Refer to Section 4.1.2.7 for more information. SQL requires the following syntax

```
type [ (p) ] 'value'
```

where *p* is an optional precision specification giving the number of fractional digits in the seconds field. Precision can be specified for `time`, `timestamp`, and `interval` types. The allowed values are mentioned above. If no precision is specified in a constant specification, it defaults to the precision of the literal value.

8.5.1.1. Dates

Table 8-10 shows some possible inputs for the `date` type.

Table 8-10. Date Input

Example	Description
1999-01-08	ISO 8601; January 8 in any mode (recommended format)
January 8, 1999	unambiguous in any `datestyle` input mode
1/8/1999	January 8 in `MDY` mode; August 1 in `DMY` mode
1/18/1999	January 18 in `MDY` mode; rejected in other modes
01/02/03	January 2, 2003 in `MDY` mode; February 1, 2003 in `DMY` mode; February 3, 2001 in `YMD` mode
1999-Jan-08	January 8 in any mode
Jan-08-1999	January 8 in any mode
08-Jan-1999	January 8 in any mode
99-Jan-08	January 8 in `YMD` mode, else error
08-Jan-99	January 8, except error in `YMD` mode
Jan-08-99	January 8, except error in `YMD` mode
19990108	ISO 8601; January 8, 1999 in any mode
990108	ISO 8601; January 8, 1999 in any mode
1999.008	year and day of year
J2451187	Julian date
January 8, 99 BC	year 99 BC

8.5.1.2. Times

The time-of-day types are `time [ (p) ] without time zone` and `time [ (p) ] with time zone`. `time` alone is equivalent to `time without time zone`.

Valid input for these types consists of a time of day followed by an optional time zone. (See Table 8-11 and Table 8-12.) If a time zone is specified in the input for `time without time zone`, it is silently ignored. You can also specify a date but it will be ignored, except when you use a time zone name that involves a daylight-savings rule, such as `America/New_York`. In this case specifying the date is required in order to determine whether standard or daylight-savings time applies. The appropriate time zone offset is recorded in the `time with time zone` value.

Table 8-11. Time Input

Example	Description
`04:05:06.789`	ISO 8601
`04:05:06`	ISO 8601
`04:05`	ISO 8601
`040506`	ISO 8601
`04:05 AM`	same as 04:05; AM does not affect value
`04:05 PM`	same as 16:05; input hour must be <= 12
`04:05:06.789-8`	ISO 8601
`04:05:06-08:00`	ISO 8601
`04:05-08:00`	ISO 8601
`040506-08`	ISO 8601
`04:05:06 PST`	time zone specified by abbreviation
`2003-04-12 04:05:06 America/New_York`	time zone specified by full name

Table 8-12. Time Zone Input

Example	Description
`PST`	Abbreviation (for Pacific Standard Time)
`America/New_York`	Full time zone name
`PST8PDT`	POSIX-style time zone specification
`-8:00`	ISO-8601 offset for PST
`-800`	ISO-8601 offset for PST
`-8`	ISO-8601 offset for PST
`zulu`	Military abbreviation for UTC
`z`	Short form of `zulu`

Refer to Section 8.5.3 for more information on how to specify time zones.

8.5.1.3. Time Stamps

Valid input for the time stamp types consists of the concatenation of a date and a time, followed by an optional time zone, followed by an optional `AD` or `BC`. (Alternatively, `AD`/`BC` can appear before the

time zone, but this is not the preferred ordering.) Thus:

```
1999-01-08 04:05:06
```

and:

```
1999-01-08 04:05:06 -8:00
```

are valid values, which follow the ISO 8601 standard. In addition, the common format:

```
January 8 04:05:06 1999 PST
```

is supported.

The SQL standard differentiates `timestamp without time zone` and `timestamp with time zone` literals by the presence of a "+" or "-" symbol and time zone offset after the time. Hence, according to the standard,

```
TIMESTAMP '2004-10-19 10:23:54'
```

is a `timestamp without time zone`, while

```
TIMESTAMP '2004-10-19 10:23:54+02'
```

is a `timestamp with time zone`. PostgreSQL never examines the content of a literal string before determining its type, and therefore will treat both of the above as `timestamp without time zone`. To ensure that a literal is treated as `timestamp with time zone`, give it the correct explicit type:

```
TIMESTAMP WITH TIME ZONE '2004-10-19 10:23:54+02'
```

In a literal that has been determined to be `timestamp without time zone`, PostgreSQL will silently ignore any time zone indication. That is, the resulting value is derived from the date/time fields in the input value, and is not adjusted for time zone.

For `timestamp with time zone`, the internally stored value is always in UTC (Universal Coordinated Time, traditionally known as Greenwich Mean Time, GMT). An input value that has an explicit time zone specified is converted to UTC using the appropriate offset for that time zone. If no time zone is stated in the input string, then it is assumed to be in the time zone indicated by the system's TimeZone parameter, and is converted to UTC using the offset for the `timezone` zone.

When a `timestamp with time zone` value is output, it is always converted from UTC to the current `timezone` zone, and displayed as local time in that zone. To see the time in another time zone, either change `timezone` or use the `AT TIME ZONE` construct (see Section 9.9.3).

Conversions between `timestamp without time zone` and `timestamp with time zone` normally assume that the `timestamp without time zone` value should be taken or given as `timezone` local time. A different time zone can be specified for the conversion using `AT TIME ZONE`.

8.5.1.4. Special Values

PostgreSQL supports several special date/time input values for convenience, as shown in Table 8-13. The values `infinity` and `-infinity` are specially represented inside the system and will be displayed unchanged; but the others are simply notational shorthands that will be converted to ordinary date/time values when read. (In particular, `now` and related strings are converted to a specific time value as soon as they are read.) All of these values need to be enclosed in single quotes when used as constants in SQL commands.

Table 8-13. Special Date/Time Inputs

Input String	Valid Types	Description
epoch	date, timestamp	1970-01-01 00:00:00+00 (Unix system time zero)
infinity	date, timestamp	later than all other time stamps
-infinity	date, timestamp	earlier than all other time stamps
now	date, time, timestamp	current transaction's start time
today	date, timestamp	midnight today
tomorrow	date, timestamp	midnight tomorrow
yesterday	date, timestamp	midnight yesterday
allballs	time	00:00:00.00 UTC

The following SQL-compatible functions can also be used to obtain the current time value for the corresponding data type: CURRENT_DATE, CURRENT_TIME, CURRENT_TIMESTAMP, LOCALTIME, LOCALTIMESTAMP. The latter four accept an optional subsecond precision specification. (See Section 9.9.4.) Note that these are SQL functions and are *not* recognized in data input strings.

8.5.2. Date/Time Output

The output format of the date/time types can be set to one of the four styles ISO 8601, SQL (Ingres), traditional POSTGRES (Unix date format), or German. The default is the ISO format. (The SQL standard requires the use of the ISO 8601 format. The name of the "SQL" output format is a historical accident.) Table 8-14 shows examples of each output style. The output of the date and time types is generally only the date or time part in accordance with the given examples. However, the POSTGRES style outputs date-only values in ISO format.

Table 8-14. Date/Time Output Styles

Style Specification	Description	Example
ISO	ISO 8601, SQL standard	1997-12-17 07:37:16-08
SQL	traditional style	12/17/1997 07:37:16.00 PST
Postgres	original style	Wed Dec 17 07:37:16 1997 PST
German	regional style	17.12.1997 07:37:16.00 PST

> **Note:** ISO 8601 specifies the use of uppercase letter T to separate the date and time. PostgreSQL accepts that format on input, but on output it uses a space rather than T, as shown above. This is for readability and for consistency with RFC 3339 as well as some other database systems.

In the SQL and POSTGRES styles, day appears before month if DMY field ordering has been specified, otherwise month appears before day. (See Section 8.5.1 for how this setting also affects interpretation of input values.) Table 8-15 shows examples.

Table 8-15. Date Order Conventions

`datestyle` Setting	Input Ordering	Example Output
`SQL, DMY`	*day*/*month*/*year*	`17/12/1997 15:37:16.00 CET`
`SQL, MDY`	*month*/*day*/*year*	`12/17/1997 07:37:16.00 PST`
`Postgres, DMY`	*day*/*month*/*year*	`Wed 17 Dec 07:37:16 1997 PST`

The date/time style can be selected by the user using the `SET datestyle` command, the DateStyle parameter in the `postgresql.conf` configuration file, or the `PGDATESTYLE` environment variable on the server or client.

The formatting function `to_char` (see Section 9.8) is also available as a more flexible way to format date/time output.

8.5.3. Time Zones

Time zones, and time-zone conventions, are influenced by political decisions, not just earth geometry. Time zones around the world became somewhat standardized during the 1900s, but continue to be prone to arbitrary changes, particularly with respect to daylight-savings rules. PostgreSQL uses the widely-used IANA (Olson) time zone database for information about historical time zone rules. For times in the future, the assumption is that the latest known rules for a given time zone will continue to be observed indefinitely far into the future.

PostgreSQL endeavors to be compatible with the SQL standard definitions for typical usage. However, the SQL standard has an odd mix of date and time types and capabilities. Two obvious problems are:

- Although the `date` type cannot have an associated time zone, the `time` type can. Time zones in the real world have little meaning unless associated with a date as well as a time, since the offset can vary through the year with daylight-saving time boundaries.
- The default time zone is specified as a constant numeric offset from UTC. It is therefore impossible to adapt to daylight-saving time when doing date/time arithmetic across DST boundaries.

To address these difficulties, we recommend using date/time types that contain both date and time when using time zones. We do *not* recommend using the type `time with time zone` (though it is supported by PostgreSQL for legacy applications and for compliance with the SQL standard). PostgreSQL assumes your local time zone for any type containing only date or time.

All timezone-aware dates and times are stored internally in UTC. They are converted to local time in the zone specified by the TimeZone configuration parameter before being displayed to the client.

PostgreSQL allows you to specify time zones in three different forms:

- A full time zone name, for example `America/New_York`. The recognized time zone names are listed in the `pg_timezone_names` view (see Section 48.72). PostgreSQL uses the widely-used IANA time zone data for this purpose, so the same time zone names are also recognized by much other software.

- A time zone abbreviation, for example `PST`. Such a specification merely defines a particular offset from UTC, in contrast to full time zone names which can imply a set of daylight savings transition-date rules as well. The recognized abbreviations are listed in the `pg_timezone_abbrevs` view (see Section 48.71). You cannot set the configuration parameters TimeZone or log_timezone to a time zone abbreviation, but you can use abbreviations in date/time input values and with the `AT TIME ZONE` operator.
- In addition to the timezone names and abbreviations, PostgreSQL will accept POSIX-style time zone specifications of the form *`STDoffset`* or *`STDoffsetDST`*, where *`STD`* is a zone abbreviation, *`offset`* is a numeric offset in hours west from UTC, and *`DST`* is an optional daylight-savings zone abbreviation, assumed to stand for one hour ahead of the given offset. For example, if `EST5EDT` were not already a recognized zone name, it would be accepted and would be functionally equivalent to United States East Coast time. In this syntax, a zone abbreviation can be a string of letters, or an arbitrary string surrounded by angle brackets (<>). When a daylight-savings zone abbreviation is present, it is assumed to be used according to the same daylight-savings transition rules used in the IANA time zone database's `posixrules` entry. In a standard PostgreSQL installation, `posixrules` is the same as `US/Eastern`, so that POSIX-style time zone specifications follow USA daylight-savings rules. If needed, you can adjust this behavior by replacing the `posixrules` file.

In short, this is the difference between abbreviations and full names: abbreviations represent a specific offset from UTC, whereas many of the full names imply a local daylight-savings time rule, and so have two possible UTC offsets. As an example, `2014-06-04 12:00 America/New_York` represents noon local time in New York, which for this particular date was Eastern Daylight Time (UTC-4). So `2014-06-04 12:00 EDT` specifies that same time instant. But `2014-06-04 12:00 EST` specifies noon Eastern Standard Time (UTC-5), regardless of whether daylight savings was nominally in effect on that date.

To complicate matters, some jurisdictions have used the same timezone abbreviation to mean different UTC offsets at different times; for example, in Moscow `MSK` has meant UTC+3 in some years and UTC+4 in others. PostgreSQL interprets such abbreviations according to whatever they meant (or had most recently meant) on the specified date; but, as with the `EST` example above, this is not necessarily the same as local civil time on that date.

One should be wary that the POSIX-style time zone feature can lead to silently accepting bogus input, since there is no check on the reasonableness of the zone abbreviations. For example, `SET TIMEZONE TO FOOBAR0` will work, leaving the system effectively using a rather peculiar abbreviation for UTC. Another issue to keep in mind is that in POSIX time zone names, positive offsets are used for locations *west* of Greenwich. Everywhere else, PostgreSQL follows the ISO-8601 convention that positive timezone offsets are *east* of Greenwich.

In all cases, timezone names and abbreviations are recognized case-insensitively. (This is a change from PostgreSQL versions prior to 8.2, which were case-sensitive in some contexts but not others.)

Neither timezone names nor abbreviations are hard-wired into the server; they are obtained from configuration files stored under `.../share/timezone/` and `.../share/timezonesets/` of the installation directory (see Section B.3).

The TimeZone configuration parameter can be set in the file `postgresql.conf`, or in any of the other standard ways described in Chapter 18. There are also some special ways to set it:

- The SQL command `SET TIME ZONE` sets the time zone for the session. This is an alternative spelling of `SET TIMEZONE TO` with a more SQL-spec-compatible syntax.
- The `PGTZ` environment variable is used by libpq clients to send a `SET TIME ZONE` command to the server upon connection.

8.5.4. Interval Input

`interval` values can be written using the following verbose syntax:

```
[@] quantity unit [quantity unit...] [direction]
```

where *quantity* is a number (possibly signed); *unit* is `microsecond`, `millisecond`, `second`, `minute`, `hour`, `day`, `week`, `month`, `year`, `decade`, `century`, `millennium`, or abbreviations or plurals of these units; *direction* can be `ago` or empty. The at sign (`@`) is optional noise. The amounts of the different units are implicitly added with appropriate sign accounting. `ago` negates all the fields. This syntax is also used for interval output, if IntervalStyle is set to `postgres_verbose`.

Quantities of days, hours, minutes, and seconds can be specified without explicit unit markings. For example, `'1 12:59:10'` is read the same as `'1 day 12 hours 59 min 10 sec'`. Also, a combination of years and months can be specified with a dash; for example `'200-10'` is read the same as `'200 years 10 months'`. (These shorter forms are in fact the only ones allowed by the SQL standard, and are used for output when `IntervalStyle` is set to `sql_standard`.)

Interval values can also be written as ISO 8601 time intervals, using either the "format with designators" of the standard's section 4.4.3.2 or the "alternative format" of section 4.4.3.3. The format with designators looks like this:

```
P quantity unit [ quantity unit ...] [ T [ quantity unit ...]]
```

The string must start with a `P`, and may include a `T` that introduces the time-of-day units. The available unit abbreviations are given in Table 8-16. Units may be omitted, and may be specified in any order, but units smaller than a day must appear after `T`. In particular, the meaning of `M` depends on whether it is before or after `T`.

Table 8-16. ISO 8601 Interval Unit Abbreviations

Abbreviation	Meaning
Y	Years
M	Months (in the date part)
W	Weeks
D	Days
H	Hours
M	Minutes (in the time part)
S	Seconds

In the alternative format:

```
P [ years-months-days ] [ T hours:minutes:seconds ]
```

the string must begin with `P`, and a `T` separates the date and time parts of the interval. The values are given as numbers similar to ISO 8601 dates.

When writing an interval constant with a *fields* specification, or when assigning a string to an interval column that was defined with a *fields* specification, the interpretation of unmarked quantities depends on the *fields*. For example `INTERVAL '1' YEAR` is read as 1 year, whereas `INTERVAL '1'` means 1 second. Also, field values "to the right" of the least significant field allowed by the

fields specification are silently discarded. For example, writing `INTERVAL '1 day 2:03:04' HOUR TO MINUTE` results in dropping the seconds field, but not the day field.

According to the SQL standard all fields of an interval value must have the same sign, so a leading negative sign applies to all fields; for example the negative sign in the interval literal `'-1 2:03:04'` applies to both the days and hour/minute/second parts. PostgreSQL allows the fields to have different signs, and traditionally treats each field in the textual representation as independently signed, so that the hour/minute/second part is considered positive in this example. If `IntervalStyle` is set to `sql_standard` then a leading sign is considered to apply to all fields (but only if no additional signs appear). Otherwise the traditional PostgreSQL interpretation is used. To avoid ambiguity, it's recommended to attach an explicit sign to each field if any field is negative.

Internally `interval` values are stored as months, days, and seconds. This is done because the number of days in a month varies, and a day can have 23 or 25 hours if a daylight savings time adjustment is involved. The months and days fields are integers while the seconds field can store fractions. Because intervals are usually created from constant strings or `timestamp` subtraction, this storage method works well in most cases. Functions `justify_days` and `justify_hours` are available for adjusting days and hours that overflow their normal ranges.

In the verbose input format, and in some fields of the more compact input formats, field values can have fractional parts; for example `'1.5 week'` or `'01:02:03.45'`. Such input is converted to the appropriate number of months, days, and seconds for storage. When this would result in a fractional number of months or days, the fraction is added to the lower-order fields using the conversion factors 1 month = 30 days and 1 day = 24 hours. For example, `'1.5 month'` becomes 1 month and 15 days. Only seconds will ever be shown as fractional on output.

Table 8-17 shows some examples of valid `interval` input.

Table 8-17. Interval Input

Example	Description
1-2	SQL standard format: 1 year 2 months
3 4:05:06	SQL standard format: 3 days 4 hours 5 minutes 6 seconds
1 year 2 months 3 days 4 hours 5 minutes 6 seconds	Traditional Postgres format: 1 year 2 months 3 days 4 hours 5 minutes 6 seconds
P1Y2M3DT4H5M6S	ISO 8601 "format with designators": same meaning as above
P0001-02-03T04:05:06	ISO 8601 "alternative format": same meaning as above

8.5.5. Interval Output

The output format of the interval type can be set to one of the four styles `sql_standard`, `postgres`, `postgres_verbose`, or `iso_8601`, using the command `SET intervalstyle`. The default is the `postgres` format. Table 8-18 shows examples of each output style.

The `sql_standard` style produces output that conforms to the SQL standard's specification for interval literal strings, if the interval value meets the standard's restrictions (either year-month only or day-time only, with no mixing of positive and negative components). Otherwise the output looks like a standard year-month literal string followed by a day-time literal string, with explicit signs added to disambiguate mixed-sign intervals.

The output of the `postgres` style matches the output of PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to `ISO`.

The output of the `postgres_verbose` style matches the output of PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to non-`ISO` output.

The output of the `iso_8601` style matches the "format with designators" described in section 4.4.3.2 of the ISO 8601 standard.

Table 8-18. Interval Output Style Examples

Style Specification	Year-Month Interval	Day-Time Interval	Mixed Interval
`sql_standard`	1-2	3 4:05:06	-1-2 +3 -4:05:06
`postgres`	1 year 2 mons	3 days 04:05:06	-1 year -2 mons +3 days -04:05:06
`postgres_verbose`	@ 1 year 2 mons	@ 3 days 4 hours 5 mins 6 secs	@ 1 year 2 mons -3 days 4 hours 5 mins 6 secs ago
`iso_8601`	P1Y2M	P3DT4H5M6S	P-1Y-2M3DT-4H-5M-6S

8.6. Boolean Type

PostgreSQL provides the standard SQL type `boolean`; see Table 8-19. The `boolean` type can have several states: "true", "false", and a third state, "unknown", which is represented by the SQL null value.

Table 8-19. Boolean Data Type

Name	Storage Size	Description
`boolean`	1 byte	state of true or false

Valid literal values for the "true" state are:

```
TRUE
't'
'true'
'y'
'yes'
'on'
'1'
```

For the "false" state, the following values can be used:

```
FALSE
'f'
'false'
'n'
```

```
  'no'
  'off'
  '0'
```

Leading or trailing whitespace is ignored, and case does not matter. The key words `TRUE` and `FALSE` are the preferred (SQL-compliant) usage.

Example 8-2 shows that `boolean` values are output using the letters `t` and `f`.

Example 8-2. Using the `boolean` Type

```
CREATE TABLE test1 (a boolean, b text);
INSERT INTO test1 VALUES (TRUE, 'sic est');
INSERT INTO test1 VALUES (FALSE, 'non est');
SELECT * FROM test1;
 a |    b
---+---------
 t | sic est
 f | non est

SELECT * FROM test1 WHERE a;
 a |    b
---+---------
 t | sic est
```

8.7. Enumerated Types

Enumerated (enum) types are data types that comprise a static, ordered set of values. They are equivalent to the `enum` types supported in a number of programming languages. An example of an enum type might be the days of the week, or a set of status values for a piece of data.

8.7.1. Declaration of Enumerated Types

Enum types are created using the CREATE TYPE command, for example:

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
```

Once created, the enum type can be used in table and function definitions much like any other type:

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
CREATE TABLE person (
    name text,
    current_mood mood
);
INSERT INTO person VALUES ('Moe', 'happy');
SELECT * FROM person WHERE current_mood = 'happy';
 name | current_mood
------+--------------
 Moe  | happy
(1 row)
```

8.7.2. Ordering

The ordering of the values in an enum type is the order in which the values were listed when the type was created. All standard comparison operators and related aggregate functions are supported for enums. For example:

```
INSERT INTO person VALUES ('Larry', 'sad');
INSERT INTO person VALUES ('Curly', 'ok');
SELECT * FROM person WHERE current_mood > 'sad';
 name  | current_mood
-------+--------------
 Moe   | happy
 Curly | ok
(2 rows)

SELECT * FROM person WHERE current_mood > 'sad' ORDER BY current_mood;
 name  | current_mood
-------+--------------
 Curly | ok
 Moe   | happy
(2 rows)

SELECT name
FROM person
WHERE current_mood = (SELECT MIN(current_mood) FROM person);
 name
-------
 Larry
(1 row)
```

8.7.3. Type Safety

Each enumerated data type is separate and cannot be compared with other enumerated types. See this example:

```
CREATE TYPE happiness AS ENUM ('happy', 'very happy', 'ecstatic');
CREATE TABLE holidays (
    num_weeks integer,
    happiness happiness
);
INSERT INTO holidays(num_weeks,happiness) VALUES (4, 'happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (6, 'very happy');
INSERT INTO holidays(num_weeks,happiness) VALUES (8, 'ecstatic');
INSERT INTO holidays(num_weeks,happiness) VALUES (2, 'sad');
ERROR:  invalid input value for enum happiness: "sad"
SELECT person.name, holidays.num_weeks FROM person, holidays
  WHERE person.current_mood = holidays.happiness;
ERROR:  operator does not exist: mood = happiness
```

If you really need to do something like that, you can either write a custom operator or add explicit casts to your query:

```
SELECT person.name, holidays.num_weeks FROM person, holidays
  WHERE person.current_mood::text = holidays.happiness::text;
 name | num_weeks
------+-----------
 Moe  |         4
(1 row)
```

8.7.4. Implementation Details

An enum value occupies four bytes on disk. The length of an enum value's textual label is limited by the `NAMEDATALEN` setting compiled into PostgreSQL; in standard builds this means at most 63 bytes.

Enum labels are case sensitive, so `'happy'` is not the same as `'HAPPY'`. White space in the labels is significant too.

The translations from internal enum values to textual labels are kept in the system catalog `pg_enum`. Querying this catalog directly can be useful.

8.8. Geometric Types

Geometric data types represent two-dimensional spatial objects. Table 8-20 shows the geometric types available in PostgreSQL.

Table 8-20. Geometric Types

Name	Storage Size	Description	Representation
`point`	16 bytes	Point on a plane	(x,y)
`line`	32 bytes	Infinite line	{A,B,C}
`lseg`	32 bytes	Finite line segment	((x1,y1),(x2,y2))
`box`	32 bytes	Rectangular box	((x1,y1),(x2,y2))
`path`	16+16n bytes	Closed path (similar to polygon)	((x1,y1),...)
`path`	16+16n bytes	Open path	[(x1,y1),...]
`polygon`	40+16n bytes	Polygon (similar to closed path)	((x1,y1),...)
`circle`	24 bytes	Circle	<(x,y),r> (center point and radius)

A rich set of functions and operators is available to perform various geometric operations such as scaling, translation, rotation, and determining intersections. They are explained in Section 9.11.

8.8.1. Points

Points are the fundamental two-dimensional building block for geometric types. Values of type `point` are specified using either of the following syntaxes:

```
( x , y )
```

```
  x , y
```

where *x* and *y* are the respective coordinates, as floating-point numbers.

Points are output using the first syntax.

8.8.2. Lines

Lines are represented by the linear equation $Ax + By + C = 0$, where *A* and *B* are not both zero. Values of type `line` are input and output in the following form:

```
{ A, B, C }
```

Alternatively, any of the following forms can be used for input:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]
( ( x1 , y1 ) , ( x2 , y2 ) )
  ( x1 , y1 ) , ( x2 , y2 )
    x1 , y1   ,   x2 , y2
```

where `(x1,y1)` and `(x2,y2)` are two different points on the line.

8.8.3. Line Segments

Line segments are represented by pairs of points that are the endpoints of the segment. Values of type `lseg` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ( x2 , y2 ) ]
( ( x1 , y1 ) , ( x2 , y2 ) )
  ( x1 , y1 ) , ( x2 , y2 )
    x1 , y1   ,   x2 , y2
```

where `(x1,y1)` and `(x2,y2)` are the end points of the line segment.

Line segments are output using the first syntax.

8.8.4. Boxes

Boxes are represented by pairs of points that are opposite corners of the box. Values of type `box` are specified using any of the following syntaxes:

```
( ( x1 , y1 ) , ( x2 , y2 ) )
  ( x1 , y1 ) , ( x2 , y2 )
    x1 , y1   ,   x2 , y2
```

where `(x1,y1)` and `(x2,y2)` are any two opposite corners of the box.

Boxes are output using the second syntax.

Any two opposite corners can be supplied on input, but the values will be reordered as needed to store the upper right and lower left corners, in that order.

8.8.5. Paths

Paths are represented by lists of connected points. Paths can be *open*, where the first and last points in the list are considered not connected, or *closed*, where the first and last points are considered connected.

Values of type `path` are specified using any of the following syntaxes:

```
[ ( x1 , y1 ) , ... , ( xn , yn ) ]
( ( x1 , y1 ) , ... , ( xn , yn ) )
  ( x1 , y1 ) , ... , ( xn , yn )
  ( x1 , y1   , ... ,   xn , yn )
    x1 , y1   , ... ,   xn , yn
```

where the points are the end points of the line segments comprising the path. Square brackets (`[]`) indicate an open path, while parentheses (`()`) indicate a closed path. When the outermost parentheses are omitted, as in the third through fifth syntaxes, a closed path is assumed.

Paths are output using the first or second syntax, as appropriate.

8.8.6. Polygons

Polygons are represented by lists of points (the vertexes of the polygon). Polygons are very similar to closed paths, but are stored differently and have their own set of support routines.

Values of type `polygon` are specified using any of the following syntaxes:

```
( ( x1 , y1 ) , ... , ( xn , yn ) )
  ( x1 , y1 ) , ... , ( xn , yn )
  ( x1 , y1   , ... ,   xn , yn )
    x1 , y1   , ... ,   xn , yn
```

where the points are the end points of the line segments comprising the boundary of the polygon.

Polygons are output using the first syntax.

8.8.7. Circles

Circles are represented by a center point and radius. Values of type `circle` are specified using any of the following syntaxes:

```
< ( x , y ) , r >
( ( x , y ) , r )
  ( x , y ) , r
    x , y   , r
```

where `(x,y)` is the center point and `r` is the radius of the circle.

Circles are output using the first syntax.

8.9. Network Address Types

PostgreSQL offers data types to store IPv4, IPv6, and MAC addresses, as shown in Table 8-21. It is better to use these types instead of plain text types to store network addresses, because these types offer input error checking and specialized operators and functions (see Section 9.12).

Table 8-21. Network Address Types

Name	Storage Size	Description
`cidr`	7 or 19 bytes	IPv4 and IPv6 networks
`inet`	7 or 19 bytes	IPv4 and IPv6 hosts and networks
`macaddr`	6 bytes	MAC addresses

When sorting `inet` or `cidr` data types, IPv4 addresses will always sort before IPv6 addresses, including IPv4 addresses encapsulated or mapped to IPv6 addresses, such as ::10.2.3.4 or ::ffff:10.4.3.2.

8.9.1. `inet`

The `inet` type holds an IPv4 or IPv6 host address, and optionally its subnet, all in one field. The subnet is represented by the number of network address bits present in the host address (the "netmask"). If the netmask is 32 and the address is IPv4, then the value does not indicate a subnet, only a single host. In IPv6, the address length is 128 bits, so 128 bits specify a unique host address. Note that if you want to accept only networks, you should use the `cidr` type rather than `inet`.

The input format for this type is *`address/y`* where *`address`* is an IPv4 or IPv6 address and *`y`* is the number of bits in the netmask. If the *`/y`* portion is missing, the netmask is 32 for IPv4 and 128 for IPv6, so the value represents just a single host. On display, the *`/y`* portion is suppressed if the netmask specifies a single host.

8.9.2. `cidr`

The `cidr` type holds an IPv4 or IPv6 network specification. Input and output formats follow Classless Internet Domain Routing conventions. The format for specifying networks is *`address/y`* where *`address`* is the network represented as an IPv4 or IPv6 address, and *`y`* is the number of bits in the netmask. If *`y`* is omitted, it is calculated using assumptions from the older classful network numbering system, except it will be at least large enough to include all of the octets written in the input. It is an error to specify a network address that has bits set to the right of the specified netmask.

Table 8-22 shows some examples.

Table 8-22. `cidr` Type Input Examples

`cidr` Input	`cidr` Output	`abbrev(cidr)`
192.168.100.128/25	192.168.100.128/25	192.168.100.128/25
192.168/24	192.168.0.0/24	192.168.0/24
192.168/25	192.168.0.0/25	192.168.0.0/25
192.168.1	192.168.1.0/24	192.168.1/24
192.168	192.168.0.0/24	192.168.0/24

cidr Input	cidr Output	abbrev(cidr)
128.1	128.1.0.0/16	128.1/16
128	128.0.0.0/16	128.0/16
128.1.2	128.1.2.0/24	128.1.2/24
10.1.2	10.1.2.0/24	10.1.2/24
10.1	10.1.0.0/16	10.1/16
10	10.0.0.0/8	10/8
10.1.2.3/32	10.1.2.3/32	10.1.2.3/32
2001:4f8:3:ba::/64	2001:4f8:3:ba::/64	2001:4f8:3:ba::/64
2001:4f8:3:ba:2e0:81ff:fe22:d1f1/128	2001:4f8:3:ba:2e0:81ff:fe22:d1f1/128	2001:4f8:3:ba:2e0:81ff:fe22:d1f1
::ffff:1.2.3.0/120	::ffff:1.2.3.0/120	::ffff:1.2.3/120
::ffff:1.2.3.0/128	::ffff:1.2.3.0/128	::ffff:1.2.3.0/128

8.9.3. inet vs. cidr

The essential difference between `inet` and `cidr` data types is that `inet` accepts values with nonzero bits to the right of the netmask, whereas `cidr` does not.

> **Tip:** If you do not like the output format for `inet` or `cidr` values, try the functions `host`, `text`, and `abbrev`.

8.9.4. macaddr

The `macaddr` type stores MAC addresses, known for example from Ethernet card hardware addresses (although MAC addresses are used for other purposes as well). Input is accepted in the following formats:

```
'08:00:2b:01:02:03'
'08-00-2b-01-02-03'
'08002b:010203'
'08002b-010203'
'0800.2b01.0203'
'08002b010203'
```

These examples would all specify the same address. Upper and lower case is accepted for the digits `a` through `f`. Output is always in the first of the forms shown.

IEEE Std 802-2001 specifies the second shown form (with hyphens) as the canonical form for MAC addresses, and specifies the first form (with colons) as the bit-reversed notation, so that 08-00-2b-01-02-03 = 01:00:4D:08:04:0C. This convention is widely ignored nowadays, and it is relevant only for obsolete network protocols (such as Token Ring). PostgreSQL makes no provisions for bit reversal, and all accepted formats use the canonical LSB order.

The remaining four input formats are not part of any standard.

8.10. Bit String Types

Bit strings are strings of 1's and 0's. They can be used to store or visualize bit masks. There are two SQL bit types: `bit(n)` and `bit varying(n)`, where *n* is a positive integer.

`bit` type data must match the length *n* exactly; it is an error to attempt to store shorter or longer bit strings. `bit varying` data is of variable length up to the maximum length *n*; longer strings will be rejected. Writing `bit` without a length is equivalent to `bit(1)`, while `bit varying` without a length specification means unlimited length.

> **Note:** If one explicitly casts a bit-string value to `bit(n)`, it will be truncated or zero-padded on the right to be exactly *n* bits, without raising an error. Similarly, if one explicitly casts a bit-string value to `bit varying(n)`, it will be truncated on the right if it is more than *n* bits.

Refer to Section 4.1.2.5 for information about the syntax of bit string constants. Bit-logical operators and string manipulation functions are available; see Section 9.6.

Example 8-3. Using the Bit String Types

```
CREATE TABLE test (a BIT(3), b BIT VARYING(5));
INSERT INTO test VALUES (B'101', B'00');
INSERT INTO test VALUES (B'10', B'101');
ERROR:  bit string length 2 does not match type bit(3)
INSERT INTO test VALUES (B'10'::bit(3), B'101');
SELECT * FROM test;
  a  |  b
-----+-----
 101 | 00
 100 | 101
```

A bit string value requires 1 byte for each group of 8 bits, plus 5 or 8 bytes overhead depending on the length of the string (but long values may be compressed or moved out-of-line, as explained in Section 8.3 for character strings).

8.11. Text Search Types

PostgreSQL provides two data types that are designed to support full text search, which is the activity of searching through a collection of natural-language *documents* to locate those that best match a *query*. The `tsvector` type represents a document in a form optimized for text search; the `tsquery` type similarly represents a text query. Chapter 12 provides a detailed explanation of this facility, and Section 9.13 summarizes the related functions and operators.

8.11.1. `tsvector`

A `tsvector` value is a sorted list of distinct *lexemes*, which are words that have been *normalized* to merge different variants of the same word (see Chapter 12 for details). Sorting and duplicate-elimination are done automatically during input, as shown in this example:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector;
                      tsvector
----------------------------------------------------
```

```
 'a' 'and' 'ate' 'cat' 'fat' 'mat' 'on' 'rat' 'sat'
```

To represent lexemes containing whitespace or punctuation, surround them with quotes:

```
SELECT $$the lexeme '    ' contains spaces$$::tsvector;
                tsvector
-------------------------------------------
 '    ' 'contains' 'lexeme' 'spaces' 'the'
```

(We use dollar-quoted string literals in this example and the next one to avoid the confusion of having to double quote marks within the literals.) Embedded quotes and backslashes must be doubled:

```
SELECT $$the lexeme 'Joe"s' contains a quote$$::tsvector;
                    tsvector
------------------------------------------------
 'Joe"s' 'a' 'contains' 'lexeme' 'quote' 'the'
```

Optionally, integer *positions* can be attached to lexemes:

```
SELECT 'a:1 fat:2 cat:3 sat:4 on:5 a:6 mat:7 and:8 ate:9 a:10 fat:11 rat:12'::tsvector;
                                  tsvector
-------------------------------------------------------------------------------
 'a':1,6,10 'and':8 'ate':9 'cat':3 'fat':2,11 'mat':7 'on':5 'rat':12 'sat':4
```

A position normally indicates the source word's location in the document. Positional information can be used for *proximity ranking*. Position values can range from 1 to 16383; larger numbers are silently set to 16383. Duplicate positions for the same lexeme are discarded.

Lexemes that have positions can further be labeled with a *weight*, which can be `A`, `B`, `C`, or `D`. `D` is the default and hence is not shown on output:

```
SELECT 'a:1A fat:2B,4C cat:5D'::tsvector;
          tsvector
----------------------------
 'a':1A 'cat':5 'fat':2B,4C
```

Weights are typically used to reflect document structure, for example by marking title words differently from body words. Text search ranking functions can assign different priorities to the different weight markers.

It is important to understand that the `tsvector` type itself does not perform any normalization; it assumes the words it is given are normalized appropriately for the application. For example,

```
select 'The Fat Rats'::tsvector;
      tsvector
--------------------
 'Fat' 'Rats' 'The'
```

For most English-text-searching applications the above words would be considered non-normalized, but `tsvector` doesn't care. Raw document text should usually be passed through `to_tsvector` to normalize the words appropriately for searching:

```
SELECT to_tsvector('english', 'The Fat Rats');
   to_tsvector
-----------------
 'fat':2 'rat':3
```

Again, see Chapter 12 for more detail.

8.11.2. tsquery

A tsquery value stores lexemes that are to be searched for, and combines them honoring the Boolean operators & (AND), | (OR), and ! (NOT). Parentheses can be used to enforce grouping of the operators:

```
SELECT 'fat & rat'::tsquery;
    tsquery
---------------
 'fat' & 'rat'

SELECT 'fat & (rat | cat)'::tsquery;
          tsquery
---------------------------
 'fat' & ( 'rat' | 'cat' )

SELECT 'fat & rat & ! cat'::tsquery;
        tsquery
------------------------
 'fat' & 'rat' & !'cat'
```

In the absence of parentheses, ! (NOT) binds most tightly, and & (AND) binds more tightly than | (OR).

Optionally, lexemes in a tsquery can be labeled with one or more weight letters, which restricts them to match only tsvector lexemes with matching weights:

```
SELECT 'fat:ab & cat'::tsquery;
    tsquery
------------------
 'fat':AB & 'cat'
```

Also, lexemes in a tsquery can be labeled with * to specify prefix matching:

```
SELECT 'super:*'::tsquery;
  tsquery
-----------
 'super':*
```

This query will match any word in a tsvector that begins with "super". Note that prefixes are first processed by text search configurations, which means this comparison returns true:

```
SELECT to_tsvector( 'postgraduate' ) @@ to_tsquery( 'postgres:*' );
 ?column?
----------
 t
(1 row)
```

because postgres gets stemmed to postgr:

```
SELECT to_tsquery('postgres:*');
 to_tsquery
------------
 'postgr':*
(1 row)
```

which then matches postgraduate.

Quoting rules for lexemes are the same as described previously for lexemes in tsvector; and, as with tsvector, any required normalization of words must be done before converting to the tsquery type. The to_tsquery function is convenient for performing such normalization:

```
SELECT to_tsquery('Fat:ab & Cats');
    to_tsquery
------------------
 'fat':AB & 'cat'
```

8.12. UUID Type

The data type uuid stores Universally Unique Identifiers (UUID) as defined by RFC 4122, ISO/IEC 9834-8:2005, and related standards. (Some systems refer to this data type as a globally unique identifier, or GUID, instead.) This identifier is a 128-bit quantity that is generated by an algorithm chosen to make it very unlikely that the same identifier will be generated by anyone else in the known universe using the same algorithm. Therefore, for distributed systems, these identifiers provide a better uniqueness guarantee than sequence generators, which are only unique within a single database.

A UUID is written as a sequence of lower-case hexadecimal digits, in several groups separated by hyphens, specifically a group of 8 digits followed by three groups of 4 digits followed by a group of 12 digits, for a total of 32 digits representing the 128 bits. An example of a UUID in this standard form is:

```
a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11
```

PostgreSQL also accepts the following alternative forms for input: use of upper-case digits, the standard format surrounded by braces, omitting some or all hyphens, adding a hyphen after any group of four digits. Examples are:

```
A0EEBC99-9C0B-4EF8-BB6D-6BB9BD380A11
{a0eebc99-9c0b-4ef8-bb6d-6bb9bd380a11}
a0eebc999c0b4ef8bb6d6bb9bd380a11
a0ee-bc99-9c0b-4ef8-bb6d-6bb9-bd38-0a11
{a0eebc99-9c0b4ef8-bb6d6bb9-bd380a11}
```

Output is always in the standard form.

PostgreSQL provides storage and comparison functions for UUIDs, but the core database does not include any function for generating UUIDs, because no single algorithm is well suited for every application. The uuid-ossp module provides functions that implement several standard algorithms. The pgcrypto module also provides a generation function for random UUIDs. Alternatively, UUIDs could be generated by client applications or other libraries invoked through a server-side function.

8.13. XML Type

The xml data type can be used to store XML data. Its advantage over storing XML data in a text field is that it checks the input values for well-formedness, and there are support functions to perform type-safe operations on it; see Section 9.14. Use of this data type requires the installation to have been built with configure --with-libxml.

The xml type can store well-formed "documents", as defined by the XML standard, as well as "content" fragments, which are defined by the production XMLDecl? content in the XML standard. Roughly, this means that content fragments can have more than one top-level element or character node. The expression *xmlvalue* IS DOCUMENT can be used to evaluate whether a particular xml value is a full document or only a content fragment.

8.13.1. Creating XML Values

To produce a value of type xml from character data, use the function xmlparse:

```
XMLPARSE ( { DOCUMENT | CONTENT } value)
```

Examples:

```
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapte
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>')
```

While this is the only way to convert character strings into XML values according to the SQL standard, the PostgreSQL-specific syntaxes:

```
xml '<foo>bar</foo>'
'<foo>bar</foo>'::xml
```

can also be used.

The xml type does not validate input values against a document type declaration (DTD), even when the input value specifies a DTD. There is also currently no built-in support for validating against other XML schema languages such as XML Schema.

The inverse operation, producing a character string value from xml, uses the function xmlserialize:

```
XMLSERIALIZE ( { DOCUMENT | CONTENT } value AS type )
```

type can be character, character varying, or text (or an alias for one of those). Again, according to the SQL standard, this is the only way to convert between type xml and character types, but PostgreSQL also allows you to simply cast the value.

When a character string value is cast to or from type xml without going through XMLPARSE or XMLSERIALIZE, respectively, the choice of DOCUMENT versus CONTENT is determined by the "XML option" session configuration parameter, which can be set using the standard command:

```
SET XML OPTION { DOCUMENT | CONTENT };
```

or the more PostgreSQL-like syntax

```
SET xmloption TO { DOCUMENT | CONTENT };
```

The default is CONTENT, so all forms of XML data are allowed.

> **Note:** With the default XML option setting, you cannot directly cast character strings to type xml if they contain a document type declaration, because the definition of XML content fragment does not accept them. If you need to do that, either use XMLPARSE or change the XML option.

8.13.2. Encoding Handling

Care must be taken when dealing with multiple character encodings on the client, server, and in the XML data passed through them. When using the text mode to pass queries to the server and query results to the client (which is the normal mode), PostgreSQL converts all character data passed between the client and the server and vice versa to the character encoding of the respective end; see Section 22.3. This includes string representations of XML values, such as in the above examples. This would ordinarily mean that encoding declarations contained in XML data can become invalid as the character data is converted to other encodings while traveling between client and server, because the embedded encoding declaration is not changed. To cope with this behavior, encoding declarations contained in character strings presented for input to the `xml` type are *ignored*, and content is assumed to be in the current server encoding. Consequently, for correct processing, character strings of XML data must be sent from the client in the current client encoding. It is the responsibility of the client to either convert documents to the current client encoding before sending them to the server, or to adjust the client encoding appropriately. On output, values of type `xml` will not have an encoding declaration, and clients should assume all data is in the current client encoding.

When using binary mode to pass query parameters to the server and query results back to the client, no character set conversion is performed, so the situation is different. In this case, an encoding declaration in the XML data will be observed, and if it is absent, the data will be assumed to be in UTF-8 (as required by the XML standard; note that PostgreSQL does not support UTF-16). On output, data will have an encoding declaration specifying the client encoding, unless the client encoding is UTF-8, in which case it will be omitted.

Needless to say, processing XML data with PostgreSQL will be less error-prone and more efficient if the XML data encoding, client encoding, and server encoding are the same. Since XML data is internally processed in UTF-8, computations will be most efficient if the server encoding is also UTF-8.

> **Caution**
>
> Some XML-related functions may not work at all on non-ASCII data when the server encoding is not UTF-8. This is known to be an issue for `xpath()` in particular.

8.13.3. Accessing XML Values

The `xml` data type is unusual in that it does not provide any comparison operators. This is because there is no well-defined and universally useful comparison algorithm for XML data. One consequence of this is that you cannot retrieve rows by comparing an `xml` column against a search value. XML values should therefore typically be accompanied by a separate key field such as an ID. An alternative solution for comparing XML values is to convert them to character strings first, but note that character string comparison has little to do with a useful XML comparison method.

Since there are no comparison operators for the `xml` data type, it is not possible to create an index directly on a column of this type. If speedy searches in XML data are desired, possible workarounds include casting the expression to a character string type and indexing that, or indexing an XPath expression. Of course, the actual query would have to be adjusted to search by the indexed expression.

The text-search functionality in PostgreSQL can also be used to speed up full-document searches of XML data. The necessary preprocessing support is, however, not yet available in the PostgreSQL distribution.

8.14. JSON Types

JSON data types are for storing JSON (JavaScript Object Notation) data, as specified in RFC 7159[1]. Such data can also be stored as `text`, but the JSON data types have the advantage of enforcing that each stored value is valid according to the JSON rules. There are also assorted JSON-specific functions and operators available for data stored in these data types; see Section 9.15.

There are two JSON data types: `json` and `jsonb`. They accept *almost* identical sets of values as input. The major practical difference is one of efficiency. The `json` data type stores an exact copy of the input text, which processing functions must reparse on each execution; while `jsonb` data is stored in a decomposed binary format that makes it slightly slower to input due to added conversion overhead, but significantly faster to process, since no reparsing is needed. `jsonb` also supports indexing, which can be a significant advantage.

Because the `json` type stores an exact copy of the input text, it will preserve semantically-insignificant white space between tokens, as well as the order of keys within JSON objects. Also, if a JSON object within the value contains the same key more than once, all the key/value pairs are kept. (The processing functions consider the last value as the operative one.) By contrast, `jsonb` does not preserve white space, does not preserve the order of object keys, and does not keep duplicate object keys. If duplicate keys are specified in the input, only the last value is kept.

In general, most applications should prefer to store JSON data as `jsonb`, unless there are quite specialized needs, such as legacy assumptions about ordering of object keys.

PostgreSQL allows only one character set encoding per database. It is therefore not possible for the JSON types to conform rigidly to the JSON specification unless the database encoding is UTF8. Attempts to directly include characters that cannot be represented in the database encoding will fail; conversely, characters that can be represented in the database encoding but not in UTF8 will be allowed.

RFC 7159 permits JSON strings to contain Unicode escape sequences denoted by `\u`*`XXXX`*. In the input function for the `json` type, Unicode escapes are allowed regardless of the database encoding, and are checked only for syntactic correctness (that is, that four hex digits follow `\u`). However, the input function for `jsonb` is stricter: it disallows Unicode escapes for non-ASCII characters (those above `U+007F`) unless the database encoding is UTF8. The `jsonb` type also rejects `\u0000` (because that cannot be represented in PostgreSQL's `text` type), and it insists that any use of Unicode surrogate pairs to designate characters outside the Unicode Basic Multilingual Plane be correct. Valid Unicode escapes are converted to the equivalent ASCII or UTF8 character for storage; this includes folding surrogate pairs into a single character.

> **Note:** Many of the JSON processing functions described in Section 9.15 will convert Unicode escapes to regular characters, and will therefore throw the same types of errors just described even if their input is of type `json` not `jsonb`. The fact that the `json` input function does not make these checks may be considered a historical artifact, although it does allow for simple storage (without processing) of JSON Unicode escapes in a non-UTF8 database encoding. In general, it is best to avoid mixing Unicode escapes in JSON with a non-UTF8 database encoding, if possible.

When converting textual JSON input into `jsonb`, the primitive types described by RFC 7159 are effectively mapped onto native PostgreSQL types, as shown in Table 8-23. Therefore, there are some minor additional constraints on what constitutes valid `jsonb` data that do not apply to the `json` type, nor to JSON in the abstract, corresponding to limits on what can be represented by the underlying data type. Notably, `jsonb` will reject numbers that are outside the range of the PostgreSQL `numeric` data type, while `json` will not. Such implementation-defined restrictions are permitted by RFC 7159.

1. http://rfc7159.net/rfc7159

However, in practice such problems are far more likely to occur in other implementations, as it is common to represent JSON's `number` primitive type as IEEE 754 double precision floating point (which RFC 7159 explicitly anticipates and allows for). When using JSON as an interchange format with such systems, the danger of losing numeric precision compared to data originally stored by PostgreSQL should be considered.

Conversely, as noted in the table there are some minor restrictions on the input format of JSON primitive types that do not apply to the corresponding PostgreSQL types.

Table 8-23. JSON primitive types and corresponding PostgreSQL types

JSON primitive type	PostgreSQL type	Notes
`string`	`text`	`\u0000` is disallowed, as are non-ASCII Unicode escapes if database encoding is not UTF8
`number`	`numeric`	`NaN` and `infinity` values are disallowed
`boolean`	`boolean`	Only lowercase `true` and `false` spellings are accepted
`null`	(none)	SQL `NULL` is a different concept

8.14.1. JSON Input and Output Syntax

The input/output syntax for the JSON data types is as specified in RFC 7159.

The following are all valid `json` (or `jsonb`) expressions:

```
-- Simple scalar/primitive value
-- Primitive values can be numbers, quoted strings, true, false, or null
SELECT '5'::json;

-- Array of zero or more elements (elements need not be of same type)
SELECT '[1, 2, "foo", null]'::json;

-- Object containing pairs of keys and values
-- Note that object keys must always be quoted strings
SELECT '{"bar": "baz", "balance": 7.77, "active": false}'::json;

-- Arrays and objects can be nested arbitrarily
SELECT '{"foo": [true, "bar"], "tags": {"a": 1, "b": null}}'::json;
```

As previously stated, when a JSON value is input and then printed without any additional processing, `json` outputs the same text that was input, while `jsonb` does not preserve semantically-insignificant details such as whitespace. For example, note the differences here:

```
SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::json;
                      json
-------------------------------------------------
 {"bar": "baz", "balance": 7.77, "active":false}
(1 row)

SELECT '{"bar": "baz", "balance": 7.77, "active":false}'::jsonb;
```

```
                      jsonb
-------------------------------------------------
 {"bar": "baz", "active": false, "balance": 7.77}
(1 row)
```

One semantically-insignificant detail worth noting is that in `jsonb`, numbers will be printed according to the behavior of the underlying `numeric` type. In practice this means that numbers entered with `E` notation will be printed without it, for example:

```
SELECT '{"reading": 1.230e-5}'::json, '{"reading": 1.230e-5}'::jsonb;
         json          |          jsonb
-----------------------+-------------------------
 {"reading": 1.230e-5} | {"reading": 0.00001230}
(1 row)
```

However, `jsonb` will preserve trailing fractional zeroes, as seen in this example, even though those are semantically insignificant for purposes such as equality checks.

8.14.2. Designing JSON documents effectively

Representing data as JSON can be considerably more flexible than the traditional relational data model, which is compelling in environments where requirements are fluid. It is quite possible for both approaches to co-exist and complement each other within the same application. However, even for applications where maximal flexibility is desired, it is still recommended that JSON documents have a somewhat fixed structure. The structure is typically unenforced (though enforcing some business rules declaratively is possible), but having a predictable structure makes it easier to write queries that usefully summarize a set of "documents" (datums) in a table.

JSON data is subject to the same concurrency-control considerations as any other data type when stored in a table. Although storing large documents is practicable, keep in mind that any update acquires a row-level lock on the whole row. Consider limiting JSON documents to a manageable size in order to decrease lock contention among updating transactions. Ideally, JSON documents should each represent an atomic datum that business rules dictate cannot reasonably be further subdivided into smaller datums that could be modified independently.

8.14.3. `jsonb` Containment and Existence

Testing *containment* is an important capability of `jsonb`. There is no parallel set of facilities for the `json` type. Containment tests whether one `jsonb` document has contained within it another one. These examples return true except as noted:

```
-- Simple scalar/primitive values contain only the identical value:
SELECT '"foo"'::jsonb @> '"foo"'::jsonb;

-- The array on the right side is contained within the one on the left:
SELECT '[1, 2, 3]'::jsonb @> '[1, 3]'::jsonb;

-- Order of array elements is not significant, so this is also true:
SELECT '[1, 2, 3]'::jsonb @> '[3, 1]'::jsonb;

-- Duplicate array elements don't matter either:
SELECT '[1, 2, 3]'::jsonb @> '[1, 2, 2]'::jsonb;
```

```
-- The object with a single pair on the right side is contained
-- within the object on the left side:
SELECT '{"product": "PostgreSQL", "version": 9.4, "jsonb":true}'::jsonb @> '{"version":9

-- The array on the right side is not considered contained within the
-- array on the left, even though a similar array is nested within it:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[1, 3]'::jsonb;  -- yields false

-- But with a layer of nesting, it is contained:
SELECT '[1, 2, [1, 3]]'::jsonb @> '[[1, 3]]'::jsonb;

-- Similarly, containment is not reported here:
SELECT '{"foo": {"bar": "baz"}}'::jsonb @> '{"bar": "baz"}'::jsonb;  -- yields false
```

The general principle is that the contained object must match the containing object as to structure and data contents, possibly after discarding some non-matching array elements or object key/value pairs from the containing object. But remember that the order of array elements is not significant when doing a containment match, and duplicate array elements are effectively considered only once.

As a special exception to the general principle that the structures must match, an array may contain a primitive value:

```
-- This array contains the primitive string value:
SELECT '["foo", "bar"]'::jsonb @> '"bar"'::jsonb;

-- This exception is not reciprocal -- non-containment is reported here:
SELECT '"bar"'::jsonb @> '["bar"]'::jsonb;  -- yields false
```

`jsonb` also has an *existence* operator, which is a variation on the theme of containment: it tests whether a string (given as a `text` value) appears as an object key or array element at the top level of the `jsonb` value. These examples return true except as noted:

```
-- String exists as array element:
SELECT '["foo", "bar", "baz"]'::jsonb ? 'bar';

-- String exists as object key:
SELECT '{"foo": "bar"}'::jsonb ? 'foo';

-- Object values are not considered:
SELECT '{"foo": "bar"}'::jsonb ? 'bar';  -- yields false

-- As with containment, existence must match at the top level:
SELECT '{"foo": {"bar": "baz"}}'::jsonb ? 'bar'; -- yields false

-- A string is considered to exist if it matches a primitive JSON string:
SELECT '"foo"'::jsonb ? 'foo';
```

JSON objects are better suited than arrays for testing containment or existence when there are many keys or elements involved, because unlike arrays they are internally optimized for searching, and do not need to be searched linearly.

The various containment and existence operators, along with all other JSON operators and functions are documented in Section 9.15.

8.14.4. `jsonb` Indexing

GIN indexes can be used to efficiently search for keys or key/value pairs occurring within a large number of `jsonb` documents (datums). Two GIN "operator classes" are provided, offering different performance and flexibility trade-offs.

The default GIN operator class for `jsonb` supports queries with the `@>`, `?`, `?&` and `?|` operators. (For details of the semantics that these operators implement, see Table 9-41.) An example of creating an index with this operator class is:

```
CREATE INDEX idxgin ON api USING gin (jdoc);
```

The non-default GIN operator class `jsonb_path_ops` supports indexing the `@>` operator only. An example of creating an index with this operator class is:

```
CREATE INDEX idxginp ON api USING gin (jdoc jsonb_path_ops);
```

Consider the example of a table that stores JSON documents retrieved from a third-party web service, with a documented schema definition. A typical document is:

```
{
    "guid": "9c36adc1-7fb5-4d5b-83b4-90356a46061a",
    "name": "Angela Barton",
    "is_active": true,
    "company": "Magnafone",
    "address": "178 Howard Place, Gulf, Washington, 702",
    "registered": "2009-11-07T08:53:22 +08:00",
    "latitude": 19.793713,
    "longitude": 86.513373,
    "tags": [
        "enim",
        "aliquip",
        "qui"
    ]
}
```

We store these documents in a table named `api`, in a `jsonb` column named `jdoc`. If a GIN index is created on this column, queries like the following can make use of the index:

```
-- Find documents in which the key "company" has value "Magnafone"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"company": "Magnafone"}';
```

However, the index could not be used for queries like the following, because though the operator `?` is indexable, it is not applied directly to the indexed column `jdoc`:

```
-- Find documents in which the key "tags" contains key or array element "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc -> 'tags' ? 'qui';
```

Still, with appropriate use of expression indexes, the above query can use an index. If querying for particular items within the `"tags"` key is common, defining an index like this may be worthwhile:

```
CREATE INDEX idxgintags ON api USING gin ((jdoc -> 'tags'));
```

Now, the `WHERE` clause `jdoc -> 'tags' ? 'qui'` will be recognized as an application of the indexable operator `?` to the indexed expression `jdoc -> 'tags'`. (More information on expression indexes can be found in Section 11.7.)

Another approach to querying is to exploit containment, for example:

```
-- Find documents in which the key "tags" contains array element "qui"
SELECT jdoc->'guid', jdoc->'name' FROM api WHERE jdoc @> '{"tags": ["qui"]}';
```

A simple GIN index on the `jdoc` column can support this query. But note that such an index will store copies of every key and value in the `jdoc` column, whereas the expression index of the previous example stores only data found under the `tags` key. While the simple-index approach is far more flexible (since it supports queries about any key), targeted expression indexes are likely to be smaller and faster to search than a simple index.

Although the `jsonb_path_ops` operator class supports only queries with the `@>` operator, it has notable performance advantages over the default operator class `jsonb_ops`. A `jsonb_path_ops` index is usually much smaller than a `jsonb_ops` index over the same data, and the specificity of searches is better, particularly when queries contain keys that appear frequently in the data. Therefore search operations typically perform better than with the default operator class.

The technical difference between a `jsonb_ops` and a `jsonb_path_ops` GIN index is that the former creates independent index items for each key and value in the data, while the latter creates index items only for each value in the data. [2] Basically, each `jsonb_path_ops` index item is a hash of the value and the key(s) leading to it; for example to index `{"foo": {"bar": "baz"}}`, a single index item would be created incorporating all three of `foo`, `bar`, and `baz` into the hash value. Thus a containment query looking for this structure would result in an extremely specific index search; but there is no way at all to find out whether `foo` appears as a key. On the other hand, a `jsonb_ops` index would create three index items representing `foo`, `bar`, and `baz` separately; then to do the containment query, it would look for rows containing all three of these items. While GIN indexes can perform such an AND search fairly efficiently, it will still be less specific and slower than the equivalent `jsonb_path_ops` search, especially if there are a very large number of rows containing any single one of the three index items.

A disadvantage of the `jsonb_path_ops` approach is that it produces no index entries for JSON structures not containing any values, such as `{"a": {}}`. If a search for documents containing such a structure is requested, it will require a full-index scan, which is quite slow. `jsonb_path_ops` is therefore ill-suited for applications that often perform such searches.

`jsonb` also supports `btree` and `hash` indexes. These are usually useful only if it's important to check equality of complete JSON documents. The `btree` ordering for `jsonb` datums is seldom of great interest, but for completeness it is:

```
Object > Array > Boolean > Number > String > Null

Object with n pairs > object with n - 1 pairs

Array with n elements > array with n - 1 elements
```

Objects with equal numbers of pairs are compared in the order:

```
key-1, value-1, key-2 ...
```

Note that object keys are compared in their storage order; in particular, since shorter keys are stored before longer keys, this can lead to results that might be unintuitive, such as:

```
{ "aa": 1, "c": 1} > {"b": 1, "d": 1}
```

Similarly, arrays with equal numbers of elements are compared in the order:

2. For this purpose, the term "value" includes array elements, though JSON terminology sometimes considers array elements distinct from values within objects.

element-1, *element-2* ...

Primitive JSON values are compared using the same comparison rules as for the underlying PostgreSQL data type. Strings are compared using the default database collation.

8.15. Arrays

PostgreSQL allows columns of a table to be defined as variable-length multidimensional arrays. Arrays of any built-in or user-defined base type, enum type, or composite type can be created. Arrays of domains are not yet supported.

8.15.1. Declaration of Array Types

To illustrate the use of array types, we create this table:

```
CREATE TABLE sal_emp (
    name            text,
    pay_by_quarter  integer[],
    schedule        text[][]
);
```

As shown, an array data type is named by appending square brackets (`[]`) to the data type name of the array elements. The above command will create a table named `sal_emp` with a column of type `text` (`name`), a one-dimensional array of type `integer` (`pay_by_quarter`), which represents the employee's salary by quarter, and a two-dimensional array of `text` (`schedule`), which represents the employee's weekly schedule.

The syntax for `CREATE TABLE` allows the exact size of arrays to be specified, for example:

```
CREATE TABLE tictactoe (
    squares   integer[3][3]
);
```

However, the current implementation ignores any supplied array size limits, i.e., the behavior is the same as for arrays of unspecified length.

The current implementation does not enforce the declared number of dimensions either. Arrays of a particular element type are all considered to be of the same type, regardless of size or number of dimensions. So, declaring the array size or number of dimensions in `CREATE TABLE` is simply documentation; it does not affect run-time behavior.

An alternative syntax, which conforms to the SQL standard by using the keyword `ARRAY`, can be used for one-dimensional arrays. `pay_by_quarter` could have been defined as:

```
    pay_by_quarter  integer ARRAY[4],
```

Or, if no array size is to be specified:

```
    pay_by_quarter  integer ARRAY,
```

As before, however, PostgreSQL does not enforce the size restriction in any case.

8.15.2. Array Value Input

To write an array value as a literal constant, enclose the element values within curly braces and separate them by commas. (If you know C, this is not unlike the C syntax for initializing structures.) You can put double quotes around any element value, and must do so if it contains commas or curly braces. (More details appear below.) Thus, the general format of an array constant is the following:

```
'{ val1 delim val2 delim ... }'
```

where *delim* is the delimiter character for the type, as recorded in its `pg_type` entry. Among the standard data types provided in the PostgreSQL distribution, all use a comma (`,`), except for type `box` which uses a semicolon (`;`). Each *val* is either a constant of the array element type, or a subarray. An example of an array constant is:

```
'{{1,2,3},{4,5,6},{7,8,9}}'
```

This constant is a two-dimensional, 3-by-3 array consisting of three subarrays of integers.

To set an element of an array constant to NULL, write `NULL` for the element value. (Any upper- or lower-case variant of `NULL` will do.) If you want an actual string value "NULL", you must put double quotes around it.

(These kinds of array constants are actually only a special case of the generic type constants discussed in Section 4.1.2.7. The constant is initially treated as a string and passed to the array input conversion routine. An explicit type specification might be necessary.)

Now we can show some `INSERT` statements:

```
INSERT INTO sal_emp
    VALUES ('Bill',
    '{10000, 10000, 10000, 10000}',
    '{{"meeting", "lunch"}, {"training", "presentation"}}');

INSERT INTO sal_emp
    VALUES ('Carol',
    '{20000, 25000, 25000, 25000}',
    '{{"breakfast", "consulting"}, {"meeting", "lunch"}}');
```

The result of the previous two inserts looks like this:

```
SELECT * FROM sal_emp;
 name  |      pay_by_quarter       |                  schedule
-------+---------------------------+-------------------------------------------
 Bill  | {10000,10000,10000,10000} | {{meeting,lunch},{training,presentation}}
 Carol | {20000,25000,25000,25000} | {{breakfast,consulting},{meeting,lunch}}
(2 rows)
```

Multidimensional arrays must have matching extents for each dimension. A mismatch causes an error, for example:

```
INSERT INTO sal_emp
    VALUES ('Bill',
    '{10000, 10000, 10000, 10000}',
    '{{"meeting", "lunch"}, {"meeting"}}');
ERROR:  multidimensional arrays must have array expressions with matching dimensions
```

The ARRAY constructor syntax can also be used:

```
INSERT INTO sal_emp
    VALUES ('Bill',
    ARRAY[10000, 10000, 10000, 10000],
    ARRAY[['meeting', 'lunch'], ['training', 'presentation']]);

INSERT INTO sal_emp
    VALUES ('Carol',
    ARRAY[20000, 25000, 25000, 25000],
    ARRAY[['breakfast', 'consulting'], ['meeting', 'lunch']]);
```

Notice that the array elements are ordinary SQL constants or expressions; for instance, string literals are single quoted, instead of double quoted as they would be in an array literal. The ARRAY constructor syntax is discussed in more detail in Section 4.2.12.

8.15.3. Accessing Arrays

Now, we can run some queries on the table. First, we show how to access a single element of an array. This query retrieves the names of the employees whose pay changed in the second quarter:

```
SELECT name FROM sal_emp WHERE pay_by_quarter[1] <> pay_by_quarter[2];

 name
-------
 Carol
(1 row)
```

The array subscript numbers are written within square brackets. By default PostgreSQL uses a one-based numbering convention for arrays, that is, an array of *n* elements starts with `array[1]` and ends with `array[n]`.

This query retrieves the third quarter pay of all employees:

```
SELECT pay_by_quarter[3] FROM sal_emp;

 pay_by_quarter
----------------
          10000
          25000
(2 rows)
```

We can also access arbitrary rectangular slices of an array, or subarrays. An array slice is denoted by writing *lower-bound*:*upper-bound* for one or more array dimensions. For example, this query retrieves the first item on Bill's schedule for the first two days of the week:

```
SELECT schedule[1:2][1:1] FROM sal_emp WHERE name = 'Bill';

        schedule
------------------------
 {{meeting},{training}}
(1 row)
```

If any dimension is written as a slice, i.e., contains a colon, then all dimensions are treated as slices. Any dimension that has only a single number (no colon) is treated as being from 1 to the number specified. For example, `[2]` is treated as `[1:2]`, as in this example:

```
SELECT schedule[1:2][2] FROM sal_emp WHERE name = 'Bill';

                schedule
-----------------------------------------
 {{meeting,lunch},{training,presentation}}
(1 row)
```

To avoid confusion with the non-slice case, it's best to use slice syntax for all dimensions, e.g., `[1:2][1:1]`, not `[2][1:1]`.

An array subscript expression will return null if either the array itself or any of the subscript expressions are null. Also, null is returned if a subscript is outside the array bounds (this case does not raise an error). For example, if `schedule` currently has the dimensions `[1:3][1:2]` then referencing `schedule[3][3]` yields NULL. Similarly, an array reference with the wrong number of subscripts yields a null rather than an error.

An array slice expression likewise yields null if the array itself or any of the subscript expressions are null. However, in other cases such as selecting an array slice that is completely outside the current array bounds, a slice expression yields an empty (zero-dimensional) array instead of null. (This does not match non-slice behavior and is done for historical reasons.) If the requested slice partially overlaps the array bounds, then it is silently reduced to just the overlapping region instead of returning null.

The current dimensions of any array value can be retrieved with the `array_dims` function:

```
SELECT array_dims(schedule) FROM sal_emp WHERE name = 'Carol';

 array_dims
------------
 [1:2][1:2]
(1 row)
```

`array_dims` produces a `text` result, which is convenient for people to read but perhaps inconvenient for programs. Dimensions can also be retrieved with `array_upper` and `array_lower`, which return the upper and lower bound of a specified array dimension, respectively:

```
SELECT array_upper(schedule, 1) FROM sal_emp WHERE name = 'Carol';

 array_upper
-------------
           2
(1 row)
```

`array_length` will return the length of a specified array dimension:

```
SELECT array_length(schedule, 1) FROM sal_emp WHERE name = 'Carol';

 array_length
--------------
            2
(1 row)
```

`cardinality` returns the total number of elements in an array across all dimensions. It is effectively the number of rows a call to `unnest` would yield:

```
SELECT cardinality(schedule) FROM sal_emp WHERE name = 'Carol';

 cardinality
-------------
           4
(1 row)
```

8.15.4. Modifying Arrays

An array value can be replaced completely:

```
UPDATE sal_emp SET pay_by_quarter = '{25000,25000,27000,27000}'
    WHERE name = 'Carol';
```

or using the `ARRAY` expression syntax:

```
UPDATE sal_emp SET pay_by_quarter = ARRAY[25000,25000,27000,27000]
    WHERE name = 'Carol';
```

An array can also be updated at a single element:

```
UPDATE sal_emp SET pay_by_quarter[4] = 15000
    WHERE name = 'Bill';
```

or updated in a slice:

```
UPDATE sal_emp SET pay_by_quarter[1:2] = '{27000,27000}'
    WHERE name = 'Carol';
```

A stored array value can be enlarged by assigning to elements not already present. Any positions between those previously present and the newly assigned elements will be filled with nulls. For example, if array `myarray` currently has 4 elements, it will have six elements after an update that assigns to `myarray[6]`; `myarray[5]` will contain null. Currently, enlargement in this fashion is only allowed for one-dimensional arrays, not multidimensional arrays.

Subscripted assignment allows creation of arrays that do not use one-based subscripts. For example one might assign to `myarray[-2:7]` to create an array with subscript values from -2 to 7.

New array values can also be constructed using the concatenation operator, `||`:

```
SELECT ARRAY[1,2] || ARRAY[3,4];
 ?column?
-----------
 {1,2,3,4}
(1 row)

SELECT ARRAY[5,6] || ARRAY[[1,2],[3,4]];
      ?column?
---------------------
 {{5,6},{1,2},{3,4}}
(1 row)
```

The concatenation operator allows a single element to be pushed onto the beginning or end of a one-dimensional array. It also accepts two *N*-dimensional arrays, or an *N*-dimensional and an *N+1*-dimensional array.

When a single element is pushed onto either the beginning or end of a one-dimensional array, the result is an array with the same lower bound subscript as the array operand. For example:

```
SELECT array_dims(1 || '[0:1]={2,3}'::int[]);
 array_dims
------------
 [0:2]
(1 row)

SELECT array_dims(ARRAY[1,2] || 3);
 array_dims
------------
 [1:3]
(1 row)
```

When two arrays with an equal number of dimensions are concatenated, the result retains the lower bound subscript of the left-hand operand's outer dimension. The result is an array comprising every element of the left-hand operand followed by every element of the right-hand operand. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[3,4,5]);
 array_dims
------------
 [1:5]
(1 row)

SELECT array_dims(ARRAY[[1,2],[3,4]] || ARRAY[[5,6],[7,8],[9,0]]);
 array_dims
------------
 [1:5][1:2]
(1 row)
```

When an *N*-dimensional array is pushed onto the beginning or end of an *N+1*-dimensional array, the result is analogous to the element-array case above. Each *N*-dimensional sub-array is essentially an element of the *N+1*-dimensional array's outer dimension. For example:

```
SELECT array_dims(ARRAY[1,2] || ARRAY[[3,4],[5,6]]);
 array_dims
------------
 [1:3][1:2]
(1 row)
```

An array can also be constructed by using the functions `array_prepend`, `array_append`, or `array_cat`. The first two only support one-dimensional arrays, but `array_cat` supports multidimensional arrays. Note that the concatenation operator discussed above is preferred over direct use of these functions. In fact, these functions primarily exist for use in implementing the concatenation operator. However, they might be directly useful in the creation of user-defined aggregates. Some examples:

```
SELECT array_prepend(1, ARRAY[2,3]);
 array_prepend
---------------
 {1,2,3}
(1 row)

SELECT array_append(ARRAY[1,2], 3);
 array_append
--------------
 {1,2,3}
(1 row)

SELECT array_cat(ARRAY[1,2], ARRAY[3,4]);
 array_cat
-----------
 {1,2,3,4}
(1 row)

SELECT array_cat(ARRAY[[1,2],[3,4]], ARRAY[5,6]);
      array_cat
---------------------
 {{1,2},{3,4},{5,6}}
(1 row)

SELECT array_cat(ARRAY[5,6], ARRAY[[1,2],[3,4]]);
      array_cat
---------------------
 {{5,6},{1,2},{3,4}}
```

8.15.5. Searching in Arrays

To search for a value in an array, each value must be checked. This can be done manually, if you know the size of the array. For example:

```
SELECT * FROM sal_emp WHERE pay_by_quarter[1] = 10000 OR
                            pay_by_quarter[2] = 10000 OR
                            pay_by_quarter[3] = 10000 OR
                            pay_by_quarter[4] = 10000;
```

However, this quickly becomes tedious for large arrays, and is not helpful if the size of the array is unknown. An alternative method is described in Section 9.23. The above query could be replaced by:

```
SELECT * FROM sal_emp WHERE 10000 = ANY (pay_by_quarter);
```

In addition, you can find rows where the array has all values equal to 10000 with:

```
SELECT * FROM sal_emp WHERE 10000 = ALL (pay_by_quarter);
```

Alternatively, the `generate_subscripts` function can be used. For example:

```
SELECT * FROM
   (SELECT pay_by_quarter,
           generate_subscripts(pay_by_quarter, 1) AS s
```

```
      FROM sal_emp) AS foo
 WHERE pay_by_quarter[s] = 10000;
```

This function is described in Table 9-55.

You can also search an array using the `&&` operator, which checks whether the left operand overlaps with the right operand. For instance:

```
SELECT * FROM sal_emp WHERE pay_by_quarter && ARRAY[10000];
```

This and other array operators are further described in Section 9.18. It can be accelerated by an appropriate index, as described in Section 11.2.

> **Tip:** Arrays are not sets; searching for specific array elements can be a sign of database misdesign. Consider using a separate table with a row for each item that would be an array element. This will be easier to search, and is likely to scale better for a large number of elements.

8.15.6. Array Input and Output Syntax

The external text representation of an array value consists of items that are interpreted according to the I/O conversion rules for the array's element type, plus decoration that indicates the array structure. The decoration consists of curly braces (`{` and `}`) around the array value plus delimiter characters between adjacent items. The delimiter character is usually a comma (`,`) but can be something else: it is determined by the `typdelim` setting for the array's element type. Among the standard data types provided in the PostgreSQL distribution, all use a comma, except for type `box`, which uses a semicolon (`;`). In a multidimensional array, each dimension (row, plane, cube, etc.) gets its own level of curly braces, and delimiters must be written between adjacent curly-braced entities of the same level.

The array output routine will put double quotes around element values if they are empty strings, contain curly braces, delimiter characters, double quotes, backslashes, or white space, or match the word `NULL`. Double quotes and backslashes embedded in element values will be backslash-escaped. For numeric data types it is safe to assume that double quotes will never appear, but for textual data types one should be prepared to cope with either the presence or absence of quotes.

By default, the lower bound index value of an array's dimensions is set to one. To represent arrays with other lower bounds, the array subscript ranges can be specified explicitly before writing the array contents. This decoration consists of square brackets (`[]`) around each array dimension's lower and upper bounds, with a colon (`:`) delimiter character in between. The array dimension decoration is followed by an equal sign (`=`). For example:

```
SELECT f1[1][-2][3] AS e1, f1[1][-1][5] AS e2
 FROM (SELECT '[1:1][-2:-1][3:5]={{{1,2,3},{4,5,6}}}'::int[] AS f1) AS ss;

 e1 | e2
----+----
  1 |  6
(1 row)
```

The array output routine will include explicit dimensions in its result only when there are one or more lower bounds different from one.

If the value written for an element is NULL (in any case variant), the element is taken to be NULL. The presence of any quotes or backslashes disables this and allows the literal string value "NULL" to be entered. Also, for backward compatibility with pre-8.2 versions of PostgreSQL, the array_nulls configuration parameter can be turned off to suppress recognition of NULL as a NULL.

As shown previously, when writing an array value you can use double quotes around any individual array element. You *must* do so if the element value would otherwise confuse the array-value parser. For example, elements containing curly braces, commas (or the data type's delimiter character), double quotes, backslashes, or leading or trailing whitespace must be double-quoted. Empty strings and strings matching the word NULL must be quoted, too. To put a double quote or backslash in a quoted array element value, use escape string syntax and precede it with a backslash. Alternatively, you can avoid quotes and use backslash-escaping to protect all data characters that would otherwise be taken as array syntax.

You can add whitespace before a left brace or after a right brace. You can also add whitespace before or after any individual item string. In all of these cases the whitespace will be ignored. However, whitespace within double-quoted elements, or surrounded on both sides by non-whitespace characters of an element, is not ignored.

> **Note:** Remember that what you write in an SQL command will first be interpreted as a string literal, and then as an array. This doubles the number of backslashes you need. For example, to insert a text array value containing a backslash and a double quote, you'd need to write:
>
> ```
> INSERT ... VALUES (E'{"\\\\","\\""}');
> ```
>
> The escape string processor removes one level of backslashes, so that what arrives at the array-value parser looks like {"\\","\""}. In turn, the strings fed to the text data type's input routine become \ and " respectively. (If we were working with a data type whose input routine also treated backslashes specially, bytea for example, we might need as many as eight backslashes in the command to get one backslash into the stored array element.) Dollar quoting (see Section 4.1.2.4) can be used to avoid the need to double backslashes.

> **Tip:** The ARRAY constructor syntax (see Section 4.2.12) is often easier to work with than the array-literal syntax when writing array values in SQL commands. In ARRAY, individual element values are written the same way they would be written when not members of an array.

8.16. Composite Types

A *composite type* represents the structure of a row or record; it is essentially just a list of field names and their data types. PostgreSQL allows composite types to be used in many of the same ways that simple types can be used. For example, a column of a table can be declared to be of a composite type.

8.16.1. Declaration of Composite Types

Here are two simple examples of defining composite types:

```
CREATE TYPE complex AS (
    r       double precision,
    i       double precision
```

```
);

CREATE TYPE inventory_item AS (
    name            text,
    supplier_id     integer,
    price           numeric
);
```

The syntax is comparable to `CREATE TABLE`, except that only field names and types can be specified; no constraints (such as `NOT NULL`) can presently be included. Note that the `AS` keyword is essential; without it, the system will think a different kind of `CREATE TYPE` command is meant, and you will get odd syntax errors.

Having defined the types, we can use them to create tables:

```
CREATE TABLE on_hand (
    item      inventory_item,
    count     integer
);

INSERT INTO on_hand VALUES (ROW('fuzzy dice', 42, 1.99), 1000);
```

or functions:

```
CREATE FUNCTION price_extension(inventory_item, integer) RETURNS numeric
AS 'SELECT $1.price * $2' LANGUAGE SQL;

SELECT price_extension(item, 10) FROM on_hand;
```

Whenever you create a table, a composite type is also automatically created, with the same name as the table, to represent the table's row type. For example, had we said:

```
CREATE TABLE inventory_item (
    name            text,
    supplier_id     integer REFERENCES suppliers,
    price           numeric CHECK (price > 0)
);
```

then the same `inventory_item` composite type shown above would come into being as a byproduct, and could be used just as above. Note however an important restriction of the current implementation: since no constraints are associated with a composite type, the constraints shown in the table definition *do not apply* to values of the composite type outside the table. (A partial workaround is to use domain types as members of composite types.)

8.16.2. Composite Value Input

To write a composite value as a literal constant, enclose the field values within parentheses and separate them by commas. You can put double quotes around any field value, and must do so if it contains commas or parentheses. (More details appear below.) Thus, the general format of a composite constant is the following:

```
'( val1 , val2 , ... )'
```

An example is:

```
'("fuzzy dice",42,1.99)'
```

which would be a valid value of the `inventory_item` type defined above. To make a field be NULL, write no characters at all in its position in the list. For example, this constant specifies a NULL third field:

```
'("fuzzy dice",42,)'
```

If you want an empty string rather than NULL, write double quotes:

```
'("",42,)'
```

Here the first field is a non-NULL empty string, the third is NULL.

(These constants are actually only a special case of the generic type constants discussed in Section 4.1.2.7. The constant is initially treated as a string and passed to the composite-type input conversion routine. An explicit type specification might be necessary.)

The `ROW` expression syntax can also be used to construct composite values. In most cases this is considerably simpler to use than the string-literal syntax since you don't have to worry about multiple layers of quoting. We already used this method above:

```
ROW('fuzzy dice', 42, 1.99)
ROW('', 42, NULL)
```

The ROW keyword is actually optional as long as you have more than one field in the expression, so these can simplify to:

```
('fuzzy dice', 42, 1.99)
('', 42, NULL)
```

The `ROW` expression syntax is discussed in more detail in Section 4.2.13.

8.16.3. Accessing Composite Types

To access a field of a composite column, one writes a dot and the field name, much like selecting a field from a table name. In fact, it's so much like selecting from a table name that you often have to use parentheses to keep from confusing the parser. For example, you might try to select some subfields from our `on_hand` example table with something like:

```
SELECT item.name FROM on_hand WHERE item.price > 9.99;
```

This will not work since the name `item` is taken to be a table name, not a column name of `on_hand`, per SQL syntax rules. You must write it like this:

```
SELECT (item).name FROM on_hand WHERE (item).price > 9.99;
```

or if you need to use the table name as well (for instance in a multitable query), like this:

```
SELECT (on_hand.item).name FROM on_hand WHERE (on_hand.item).price > 9.99;
```

Now the parenthesized object is correctly interpreted as a reference to the `item` column, and then the subfield can be selected from it.

Similar syntactic issues apply whenever you select a field from a composite value. For instance, to select just one field from the result of a function that returns a composite value, you'd need to write something like:

```
SELECT (my_func(...)).field FROM ...
```

Without the extra parentheses, this will generate a syntax error.

8.16.4. Modifying Composite Types

Here are some examples of the proper syntax for inserting and updating composite columns. First, inserting or updating a whole column:

```
INSERT INTO mytab (complex_col) VALUES((1.1,2.2));

UPDATE mytab SET complex_col = ROW(1.1,2.2) WHERE ...;
```

The first example omits `ROW`, the second uses it; we could have done it either way.

We can update an individual subfield of a composite column:

```
UPDATE mytab SET complex_col.r = (complex_col).r + 1 WHERE ...;
```

Notice here that we don't need to (and indeed cannot) put parentheses around the column name appearing just after `SET`, but we do need parentheses when referencing the same column in the expression to the right of the equal sign.

And we can specify subfields as targets for `INSERT`, too:

```
INSERT INTO mytab (complex_col.r, complex_col.i) VALUES(1.1, 2.2);
```

Had we not supplied values for all the subfields of the column, the remaining subfields would have been filled with null values.

8.16.5. Composite Type Input and Output Syntax

The external text representation of a composite value consists of items that are interpreted according to the I/O conversion rules for the individual field types, plus decoration that indicates the composite structure. The decoration consists of parentheses (`(` and `)`) around the whole value, plus commas (`,`) between adjacent items. Whitespace outside the parentheses is ignored, but within the parentheses it is considered part of the field value, and might or might not be significant depending on the input conversion rules for the field data type. For example, in:

```
'(  42)'
```

the whitespace will be ignored if the field type is integer, but not if it is text.

As shown previously, when writing a composite value you can write double quotes around any individual field value. You *must* do so if the field value would otherwise confuse the composite-value parser. In particular, fields containing parentheses, commas, double quotes, or backslashes must be double-quoted. To put a double quote or backslash in a quoted composite field value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted field value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as composite syntax.

A completely empty field value (no characters at all between the commas or parentheses) represents a NULL. To write a value that is an empty string rather than NULL, write `""`.

The composite output routine will put double quotes around field values if they are empty strings or contain parentheses, commas, double quotes, backslashes, or white space. (Doing so for white space is not essential, but aids legibility.) Double quotes and backslashes embedded in field values will be doubled.

> **Note:** Remember that what you write in an SQL command will first be interpreted as a string literal, and then as a composite. This doubles the number of backslashes you need (assuming escape string syntax is used). For example, to insert a `text` field containing a double quote and a backslash in a composite value, you'd need to write:
>
> ```
> INSERT ... VALUES (E'("\\"\\\\")');
> ```
>
> The string-literal processor removes one level of backslashes, so that what arrives at the composite-value parser looks like `("\"\\")`. In turn, the string fed to the `text` data type's input routine becomes `"\`. (If we were working with a data type whose input routine also treated backslashes specially, `bytea` for example, we might need as many as eight backslashes in the command to get one backslash into the stored composite field.) Dollar quoting (see Section 4.1.2.4) can be used to avoid the need to double backslashes.

> **Tip:** The `ROW` constructor syntax is usually easier to work with than the composite-literal syntax when writing composite values in SQL commands. In `ROW`, individual field values are written the same way they would be written when not members of a composite.

8.17. Range Types

Range types are data types representing a range of values of some element type (called the range's *subtype*). For instance, ranges of `timestamp` might be used to represent the ranges of time that a meeting room is reserved. In this case the data type is `tsrange` (short for "timestamp range"), and `timestamp` is the subtype. The subtype must have a total order so that it is well-defined whether element values are within, before, or after a range of values.

Range types are useful because they represent many element values in a single range value, and because concepts such as overlapping ranges can be expressed clearly. The use of time and date ranges for scheduling purposes is the clearest example; but price ranges, measurement ranges from an instrument, and so forth can also be useful.

8.17.1. Built-in Range Types

PostgreSQL comes with the following built-in range types:

- `int4range` — Range of `integer`
- `int8range` — Range of `bigint`
- `numrange` — Range of `numeric`
- `tsrange` — Range of `timestamp without time zone`
- `tstzrange` — Range of `timestamp with time zone`

- `daterange` — Range of `date`

In addition, you can define your own range types; see CREATE TYPE for more information.

8.17.2. Examples

```
CREATE TABLE reservation (room int, during tsrange);
INSERT INTO reservation VALUES
    (1108, '[2010-01-01 14:30, 2010-01-01 15:30)');

-- Containment
SELECT int4range(10, 20) @> 3;

-- Overlaps
SELECT numrange(11.1, 22.2) && numrange(20.0, 30.0);

-- Extract the upper bound
SELECT upper(int8range(15, 25));

-- Compute the intersection
SELECT int4range(10, 20) * int4range(15, 25);

-- Is the range empty?
SELECT isempty(numrange(1, 5));
```

See Table 9-47 and Table 9-48 for complete lists of operators and functions on range types.

8.17.3. Inclusive and Exclusive Bounds

Every non-empty range has two bounds, the lower bound and the upper bound. All points between these values are included in the range. An inclusive bound means that the boundary point itself is included in the range as well, while an exclusive bound means that the boundary point is not included in the range.

In the text form of a range, an inclusive lower bound is represented by "`[`" while an exclusive lower bound is represented by "`(`". Likewise, an inclusive upper bound is represented by "`]`", while an exclusive upper bound is represented by "`)`". (See Section 8.17.5 for more details.)

The functions `lower_inc` and `upper_inc` test the inclusivity of the lower and upper bounds of a range value, respectively.

8.17.4. Infinite (Unbounded) Ranges

The lower bound of a range can be omitted, meaning that all points less than the upper bound are included in the range. Likewise, if the upper bound of the range is omitted, then all points greater than the lower bound are included in the range. If both lower and upper bounds are omitted, all values of the element type are considered to be in the range.

This is equivalent to considering that the lower bound is "minus infinity", or the upper bound is "plus infinity", respectively. But note that these infinite values are never values of the range's element type, and can never be part of the range. (So there is no such thing as an inclusive infinite bound — if you try to write one, it will automatically be converted to an exclusive bound.)

Also, some element types have a notion of "infinity", but that is just another value so far as the range type mechanisms are concerned. For example, in timestamp ranges, `[today,]` means the same thing as `[today,)`. But `[today,infinity]` means something different from `[today,infinity)` — the latter excludes the special `timestamp` value `infinity`.

The functions `lower_inf` and `upper_inf` test for infinite lower and upper bounds of a range, respectively.

8.17.5. Range Input/Output

The input for a range value must follow one of the following patterns:

```
(lower-bound,upper-bound)
(lower-bound,upper-bound]
[lower-bound,upper-bound)
[lower-bound,upper-bound]
empty
```

The parentheses or brackets indicate whether the lower and upper bounds are exclusive or inclusive, as described previously. Notice that the final pattern is `empty`, which represents an empty range (a range that contains no points).

The *`lower-bound`* may be either a string that is valid input for the subtype, or empty to indicate no lower bound. Likewise, *`upper-bound`* may be either a string that is valid input for the subtype, or empty to indicate no upper bound.

Each bound value can be quoted using `"` (double quote) characters. This is necessary if the bound value contains parentheses, brackets, commas, double quotes, or backslashes, since these characters would otherwise be taken as part of the range syntax. To put a double quote or backslash in a quoted bound value, precede it with a backslash. (Also, a pair of double quotes within a double-quoted bound value is taken to represent a double quote character, analogously to the rules for single quotes in SQL literal strings.) Alternatively, you can avoid quoting and use backslash-escaping to protect all data characters that would otherwise be taken as range syntax. Also, to write a bound value that is an empty string, write `""`, since writing nothing means an infinite bound.

Whitespace is allowed before and after the range value, but any whitespace between the parentheses or brackets is taken as part of the lower or upper bound value. (Depending on the element type, it might or might not be significant.)

> **Note:** These rules are very similar to those for writing field values in composite-type literals. See Section 8.16.5 for additional commentary.

Examples:

```
-- includes 3, does not include 7, and does include all points in between
SELECT '[3,7)'::int4range;

-- does not include either 3 or 7, but includes all points in between
SELECT '(3,7)'::int4range;

-- includes only the single point 4
SELECT '[4,4]'::int4range;

-- includes no points (and will be normalized to 'empty')
```

```
SELECT '[4,4)'::int4range;
```

8.17.6. Constructing Ranges

Each range type has a constructor function with the same name as the range type. Using the constructor function is frequently more convenient than writing a range literal constant, since it avoids the need for extra quoting of the bound values. The constructor function accepts two or three arguments. The two-argument form constructs a range in standard form (lower bound inclusive, upper bound exclusive), while the three-argument form constructs a range with bounds of the form specified by the third argument. The third argument must be one of the strings "`()`", "`(]`", "`[)`", or "`[]`". For example:

```
-- The full form is: lower bound, upper bound, and text argument indicating
-- inclusivity/exclusivity of bounds.
SELECT numrange(1.0, 14.0, '(]');

-- If the third argument is omitted, '[)' is assumed.
SELECT numrange(1.0, 14.0);

-- Although '(]' is specified here, on display the value will be converted to
-- canonical form, since int8range is a discrete range type (see below).
SELECT int8range(1, 14, '(]');

-- Using NULL for either bound causes the range to be unbounded on that side.
SELECT numrange(NULL, 2.2);
```

8.17.7. Discrete Range Types

A discrete range is one whose element type has a well-defined "step", such as `integer` or `date`. In these types two elements can be said to be adjacent, when there are no valid values between them. This contrasts with continuous ranges, where it's always (or almost always) possible to identify other element values between two given values. For example, a range over the `numeric` type is continuous, as is a range over `timestamp`. (Even though `timestamp` has limited precision, and so could theoretically be treated as discrete, it's better to consider it continuous since the step size is normally not of interest.)

Another way to think about a discrete range type is that there is a clear idea of a "next" or "previous" value for each element value. Knowing that, it is possible to convert between inclusive and exclusive representations of a range's bounds, by choosing the next or previous element value instead of the one originally given. For example, in an integer range type `[4,8]` and `(3,9)` denote the same set of values; but this would not be so for a range over numeric.

A discrete range type should have a *canonicalization* function that is aware of the desired step size for the element type. The canonicalization function is charged with converting equivalent values of the range type to have identical representations, in particular consistently inclusive or exclusive bounds. If a canonicalization function is not specified, then ranges with different formatting will always be treated as unequal, even though they might represent the same set of values in reality.

The built-in range types int4range, int8range, and daterange all use a canonical form that includes the lower bound and excludes the upper bound; that is, [). User-defined range types can use other conventions, however.

8.17.8. Defining New Range Types

Users can define their own range types. The most common reason to do this is to use ranges over subtypes not provided among the built-in range types. For example, to define a new range type of subtype float8:

```
CREATE TYPE floatrange AS RANGE (
    subtype = float8,
    subtype_diff = float8mi
);

SELECT '[1.234, 5.678]'::floatrange;
```

Because float8 has no meaningful "step", we do not define a canonicalization function in this example.

If the subtype is considered to have discrete rather than continuous values, the CREATE TYPE command should specify a canonical function. The canonicalization function takes an input range value, and must return an equivalent range value that may have different bounds and formatting. The canonical output for two ranges that represent the same set of values, for example the integer ranges [1, 7] and [1, 8), must be identical. It doesn't matter which representation you choose to be the canonical one, so long as two equivalent values with different formattings are always mapped to the same value with the same formatting. In addition to adjusting the inclusive/exclusive bounds format, a canonicalization function might round off boundary values, in case the desired step size is larger than what the subtype is capable of storing. For instance, a range type over timestamp could be defined to have a step size of an hour, in which case the canonicalization function would need to round off bounds that weren't a multiple of an hour, or perhaps throw an error instead.

Defining your own range type also allows you to specify a different subtype B-tree operator class or collation to use, so as to change the sort ordering that determines which values fall into a given range.

In addition, any range type that is meant to be used with GiST or SP-GiST indexes should define a subtype difference, or subtype_diff, function. (the index will still work without subtype_diff, but it is likely to be considerably less efficient than if a difference function is provided.) The subtype difference function takes two input values of the subtype, and returns their difference (i.e., *X* minus *Y*) represented as a float8 value. In our example above, the function that underlies the regular float8 minus operator can be used; but for any other subtype, some type conversion would be necessary. Some creative thought about how to represent differences as numbers might be needed, too. To the greatest extent possible, the subtype_diff function should agree with the sort ordering implied by the selected operator class and collation; that is, its result should be positive whenever its first argument is greater than its second according to the sort ordering.

See CREATE TYPE for more information about creating range types.

8.17.9. Indexing

GiST and SP-GiST indexes can be created for table columns of range types. For instance, to create a

GiST index:

```
CREATE INDEX reservation_idx ON reservation USING gist (during);
```

A GiST or SP-GiST index can accelerate queries involving these range operators: =, &&, <@, @>, <<, >>, -|-, &<, and &> (see Table 9-47 for more information).

In addition, B-tree and hash indexes can be created for table columns of range types. For these index types, basically the only useful range operation is equality. There is a B-tree sort ordering defined for range values, with corresponding < and > operators, but the ordering is rather arbitrary and not usually useful in the real world. Range types' B-tree and hash support is primarily meant to allow sorting and hashing internally in queries, rather than creation of actual indexes.

8.17.10. Constraints on Ranges

While UNIQUE is a natural constraint for scalar values, it is usually unsuitable for range types. Instead, an exclusion constraint is often more appropriate (see CREATE TABLE ... CONSTRAINT ... EXCLUDE). Exclusion constraints allow the specification of constraints such as "non-overlapping" on a range type. For example:

```
CREATE TABLE reservation (
    during tsrange,
    EXCLUDE USING gist (during WITH &&)
);
```

That constraint will prevent any overlapping values from existing in the table at the same time:

```
INSERT INTO reservation VALUES
    ('[2010-01-01 11:30, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO reservation VALUES
    ('[2010-01-01 14:45, 2010-01-01 15:45)');
ERROR:  conflicting key value violates exclusion constraint "reservation_during_excl"
DETAIL:  Key (during)=(["2010-01-01 14:45:00","2010-01-01 15:45:00")) conflicts
with existing key (during)=(["2010-01-01 11:30:00","2010-01-01 15:00:00")).
```

You can use the btree_gist extension to define exclusion constraints on plain scalar data types, which can then be combined with range exclusions for maximum flexibility. For example, after btree_gist is installed, the following constraint will reject overlapping ranges only if the meeting room numbers are equal:

```
CREATE EXTENSION btree_gist;
CREATE TABLE room_reservation (
    room text,
    during tsrange,
    EXCLUDE USING gist (room WITH =, during WITH &&)
);

INSERT INTO room_reservation VALUES
    ('123A', '[2010-01-01 14:00, 2010-01-01 15:00)');
INSERT 0 1

INSERT INTO room_reservation VALUES
```

```
    ('123A', '[2010-01-01 14:30, 2010-01-01 15:30)');
ERROR:  conflicting key value violates exclusion constraint "room_reservation_room_durin
DETAIL:  Key (room, during)=(123A, ["2010-01-01 14:30:00","2010-01-01 15:30:00")) confli
with existing key (room, during)=(123A, ["2010-01-01 14:00:00","2010-01-01 15:00:00")).

INSERT INTO room_reservation VALUES
    ('123B', '[2010-01-01 14:30, 2010-01-01 15:30)');
INSERT 0 1
```

8.18. Object Identifier Types

Object identifiers (OIDs) are used internally by PostgreSQL as primary keys for various system tables. OIDs are not added to user-created tables, unless `WITH OIDS` is specified when the table is created, or the default_with_oids configuration variable is enabled. Type `oid` represents an object identifier. There are also several alias types for `oid`: `regproc`, `regprocedure`, `regoper`, `regoperator`, `regclass`, `regtype`, `regconfig`, and `regdictionary`. Table 8-24 shows an overview.

The `oid` type is currently implemented as an unsigned four-byte integer. Therefore, it is not large enough to provide database-wide uniqueness in large databases, or even in large individual tables. So, using a user-created table's OID column as a primary key is discouraged. OIDs are best used only for references to system tables.

The `oid` type itself has few operations beyond comparison. It can be cast to integer, however, and then manipulated using the standard integer operators. (Beware of possible signed-versus-unsigned confusion if you do this.)

The OID alias types have no operations of their own except for specialized input and output routines. These routines are able to accept and display symbolic names for system objects, rather than the raw numeric value that type `oid` would use. The alias types allow simplified lookup of OID values for objects. For example, to examine the `pg_attribute` rows related to a table `mytable`, one could write:

```
SELECT * FROM pg_attribute WHERE attrelid = 'mytable'::regclass;
```

rather than:

```
SELECT * FROM pg_attribute
  WHERE attrelid = (SELECT oid FROM pg_class WHERE relname = 'mytable');
```

While that doesn't look all that bad by itself, it's still oversimplified. A far more complicated subselect would be needed to select the right OID if there are multiple tables named `mytable` in different schemas. The `regclass` input converter handles the table lookup according to the schema path setting, and so it does the "right thing" automatically. Similarly, casting a table's OID to `regclass` is handy for symbolic display of a numeric OID.

Table 8-24. Object Identifier Types

Name	References	Description	Value Example
`oid`	any	numeric object identifier	`564182`
`regproc`	`pg_proc`	function name	`sum`

Name	References	Description	Value Example
regprocedure	pg_proc	function with argument types	sum(int4)
regoper	pg_operator	operator name	+
regoperator	pg_operator	operator with argument types	*(integer,integer) or -(NONE,integer)
regclass	pg_class	relation name	pg_type
regtype	pg_type	data type name	integer
regconfig	pg_ts_config	text search configuration	english
regdictionary	pg_ts_dict	text search dictionary	simple

All of the OID alias types accept schema-qualified names, and will display schema-qualified names on output if the object would not be found in the current search path without being qualified. The regproc and regoper alias types will only accept input names that are unique (not overloaded), so they are of limited use; for most uses regprocedure or regoperator are more appropriate. For regoperator, unary operators are identified by writing NONE for the unused operand.

An additional property of the OID alias types is the creation of dependencies. If a constant of one of these types appears in a stored expression (such as a column default expression or view), it creates a dependency on the referenced object. For example, if a column has a default expression nextval('my_seq'::regclass), PostgreSQL understands that the default expression depends on the sequence my_seq; the system will not let the sequence be dropped without first removing the default expression.

Another identifier type used by the system is xid, or transaction (abbreviated xact) identifier. This is the data type of the system columns xmin and xmax. Transaction identifiers are 32-bit quantities.

A third identifier type used by the system is cid, or command identifier. This is the data type of the system columns cmin and cmax. Command identifiers are also 32-bit quantities.

A final identifier type used by the system is tid, or tuple identifier (row identifier). This is the data type of the system column ctid. A tuple ID is a pair (block number, tuple index within block) that identifies the physical location of the row within its table.

(The system columns are further explained in Section 5.4.)

8.19. pg_lsn Type

The pg_lsn data type can be used to store LSN (Log Sequence Number) data which is a pointer to a location in the XLOG. This type is a representation of XLogRecPtr and an internal system type of PostgreSQL.

Internally, an LSN is a 64-bit integer, representing a byte position in the write-ahead log stream. It is printed as two hexadecimal numbers of up to 8 digits each, separated by a slash; for example, 16/B374D848. The pg_lsn type supports the standard comparison operators, like = and >. Two LSNs can be subtracted using the - operator; the result is the number of bytes separating those write-ahead log positions.

8.20. Pseudo-Types

The PostgreSQL type system contains a number of special-purpose entries that are collectively called *pseudo-types*. A pseudo-type cannot be used as a column data type, but it can be used to declare a function's argument or result type. Each of the available pseudo-types is useful in situations where a function's behavior does not correspond to simply taking or returning a value of a specific SQL data type. Table 8-25 lists the existing pseudo-types.

Table 8-25. Pseudo-Types

Name	Description
`any`	Indicates that a function accepts any input data type.
`anyelement`	Indicates that a function accepts any data type (see Section 35.2.5).
`anyarray`	Indicates that a function accepts any array data type (see Section 35.2.5).
`anynonarray`	Indicates that a function accepts any non-array data type (see Section 35.2.5).
`anyenum`	Indicates that a function accepts any enum data type (see Section 35.2.5 and Section 8.7).
`anyrange`	Indicates that a function accepts any range data type (see Section 35.2.5 and Section 8.17).
`cstring`	Indicates that a function accepts or returns a null-terminated C string.
`internal`	Indicates that a function accepts or returns a server-internal data type.
`language_handler`	A procedural language call handler is declared to return `language_handler`.
`fdw_handler`	A foreign-data wrapper handler is declared to return `fdw_handler`.
`record`	Identifies a function returning an unspecified row type.
`trigger`	A trigger function is declared to return `trigger`.
`void`	Indicates that a function returns no value.
`opaque`	An obsolete type name that formerly served all the above purposes.

Functions coded in C (whether built-in or dynamically loaded) can be declared to accept or return any of these pseudo data types. It is up to the function author to ensure that the function will behave safely when a pseudo-type is used as an argument type.

Functions coded in procedural languages can use pseudo-types only as allowed by their implementation languages. At present the procedural languages all forbid use of a pseudo-type as argument type, and allow only `void` and `record` as a result type (plus `trigger` when the function is used as a trigger). Some also support polymorphic functions using the types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`.

The `internal` pseudo-type is used to declare functions that are meant only to be called internally

by the database system, and not by direct invocation in an SQL query. If a function has at least one `internal`-type argument then it cannot be called from SQL. To preserve the type safety of this restriction it is important to follow this coding rule: do not create any function that is declared to return `internal` unless it has at least one `internal` argument.

Chapter 9. Functions and Operators

PostgreSQL provides a large number of functions and operators for the built-in data types. Users can also define their own functions and operators, as described in Part V. The psql commands `\df` and `\do` can be used to list all available functions and operators, respectively.

If you are concerned about portability then note that most of the functions and operators described in this chapter, with the exception of the most trivial arithmetic and comparison operators and some explicitly marked functions, are not specified by the SQL standard. Some of this extended functionality is present in other SQL database management systems, and in many cases this functionality is compatible and consistent between the various implementations. This chapter is also not exhaustive; additional functions appear in relevant sections of the manual.

9.1. Logical Operators

The usual logical operators are available:

```
AND
OR
NOT
```

SQL uses a three-valued logic system with true, false, and `null`, which represents "unknown". Observe the following truth tables:

a	*b*	*a* AND *b*	*a* OR *b*
TRUE	TRUE	TRUE	TRUE
TRUE	FALSE	FALSE	TRUE
TRUE	NULL	NULL	TRUE
FALSE	FALSE	FALSE	FALSE
FALSE	NULL	FALSE	NULL
NULL	NULL	NULL	NULL

a	NOT *a*
TRUE	FALSE
FALSE	TRUE
NULL	NULL

The operators `AND` and `OR` are commutative, that is, you can switch the left and right operand without affecting the result. But see Section 4.2.14 for more information about the order of evaluation of subexpressions.

9.2. Comparison Operators

The usual comparison operators are available, shown in Table 9-1.

Table 9-1. Comparison Operators

Operator	Description
<	less than
>	greater than
<=	less than or equal to
>=	greater than or equal to
=	equal
<> or !=	not equal

> **Note:** The != operator is converted to <> in the parser stage. It is not possible to implement != and <> operators that do different things.

Comparison operators are available for all relevant data types. All comparison operators are binary operators that return values of type `boolean`; expressions like `1 < 2 < 3` are not valid (because there is no < operator to compare a Boolean value with `3`).

In addition to the comparison operators, the special `BETWEEN` construct is available:

```
a BETWEEN x AND y
```

is equivalent to

```
a >= x AND a <= y
```

Notice that `BETWEEN` treats the endpoint values as included in the range. `NOT BETWEEN` does the opposite comparison:

```
a NOT BETWEEN x AND y
```

is equivalent to

```
a < x OR a > y
```

`BETWEEN SYMMETRIC` is the same as `BETWEEN` except there is no requirement that the argument to the left of `AND` be less than or equal to the argument on the right. If it is not, those two arguments are automatically swapped, so that a nonempty range is always implied.

To check whether a value is or is not null, use the constructs:

```
expression IS NULL
expression IS NOT NULL
```

or the equivalent, but nonstandard, constructs:

```
expression ISNULL
expression NOTNULL
```

Do *not* write `expression = NULL` because `NULL` is not "equal to" `NULL`. (The null value represents an unknown value, and it is not known whether two unknown values are equal.) This behavior conforms to the SQL standard.

Tip: Some applications might expect that *expression* = NULL returns true if *expression* evaluates to the null value. It is highly recommended that these applications be modified to comply with the SQL standard. However, if that cannot be done the transform_null_equals configuration variable is available. If it is enabled, PostgreSQL will convert x = NULL clauses to x IS NULL.

Note: If the *expression* is row-valued, then IS NULL is true when the row expression itself is null or when all the row's fields are null, while IS NOT NULL is true when the row expression itself is non-null and all the row's fields are non-null. Because of this behavior, IS NULL and IS NOT NULL do not always return inverse results for row-valued expressions, i.e., a row-valued expression that contains both NULL and non-null values will return false for both tests. This definition conforms to the SQL standard, and is a change from the inconsistent behavior exhibited by PostgreSQL versions prior to 8.2.

Ordinary comparison operators yield null (signifying "unknown"), not true or false, when either input is null. For example, 7 = NULL yields null, as does 7 <> NULL. When this behavior is not suitable, use the IS [NOT] DISTINCT FROM constructs:

```
expression IS DISTINCT FROM expression
expression IS NOT DISTINCT FROM expression
```

For non-null inputs, IS DISTINCT FROM is the same as the <> operator. However, if both inputs are null it returns false, and if only one input is null it returns true. Similarly, IS NOT DISTINCT FROM is identical to = for non-null inputs, but it returns true when both inputs are null, and false when only one input is null. Thus, these constructs effectively act as though null were a normal data value, rather than "unknown".

Boolean values can also be tested using the constructs

```
expression IS TRUE
expression IS NOT TRUE
expression IS FALSE
expression IS NOT FALSE
expression IS UNKNOWN
expression IS NOT UNKNOWN
```

These will always return true or false, never a null value, even when the operand is null. A null input is treated as the logical value "unknown". Notice that IS UNKNOWN and IS NOT UNKNOWN are effectively the same as IS NULL and IS NOT NULL, respectively, except that the input expression must be of Boolean type.

9.3. Mathematical Functions and Operators

Mathematical operators are provided for many PostgreSQL types. For types without standard mathematical conventions (e.g., date/time types) we describe the actual behavior in subsequent sections.

Table 9-2 shows the available mathematical operators.

Table 9-2. Mathematical Operators

Operator	Description	Example	Result

Operator	Description	Example	Result
+	addition	2 + 3	5
-	subtraction	2 - 3	-1
*	multiplication	2 * 3	6
/	division (integer division truncates the result)	4 / 2	2
%	modulo (remainder)	5 % 4	1
^	exponentiation	2.0 ^ 3.0	8
|/	square root	|/ 25.0	5
||/	cube root	||/ 27.0	3
!	factorial	5 !	120
!!	factorial (prefix operator)	!! 5	120
@	absolute value	@ -5.0	5
&	bitwise AND	91 & 15	11
|	bitwise OR	32 | 3	35
#	bitwise XOR	17 # 5	20
~	bitwise NOT	~1	-2
<<	bitwise shift left	1 << 4	16
>>	bitwise shift right	8 >> 2	2

The bitwise operators work only on integral data types, whereas the others are available for all numeric data types. The bitwise operators are also available for the bit string types `bit` and `bit varying`, as shown in Table 9-11.

Table 9-3 shows the available mathematical functions. In the table, `dp` indicates `double precision`. Many of these functions are provided in multiple forms with different argument types. Except where noted, any given form of a function returns the same data type as its argument. The functions working with `double precision` data are mostly implemented on top of the host system's C library; accuracy and behavior in boundary cases can therefore vary depending on the host system.

Table 9-3. Mathematical Functions

Function	Return Type	Description	Example	Result
abs(*x*)	(same as input)	absolute value	abs(-17.4)	17.4
cbrt(dp)	dp	cube root	cbrt(27.0)	3
ceil(dp or numeric)	(same as input)	smallest integer not less than argument	ceil(-42.8)	-42
ceiling(dp or numeric)	(same as input)	smallest integer not less than argument (alias for ceil)	ceiling(-95.3)	-95
degrees(dp)	dp	radians to degrees	degrees(0.5)	28.6478897565412

Function	Return Type	Description	Example	Result
div(y numeric, x numeric)	numeric	integer quotient of y/x	div(9,4)	2
exp(dp or numeric)	(same as input)	exponential	exp(1.0)	2.71828182845905
floor(dp or numeric)	(same as input)	largest integer not greater than argument	floor(-42.8)	-43
ln(dp or numeric)	(same as input)	natural logarithm	ln(2.0)	0.693147180559945
log(dp or numeric)	(same as input)	base 10 logarithm	log(100.0)	2
log(b numeric, x numeric)	numeric	logarithm to base b	log(2.0, 64.0)	6.0000000000
mod(y, x)	(same as argument types)	remainder of y/x	mod(9,4)	1
pi()	dp	"π" constant	pi()	3.14159265358979
power(a dp, b dp)	dp	a raised to the power of b	power(9.0, 3.0)	729
power(a numeric, b numeric)	numeric	a raised to the power of b	power(9.0, 3.0)	729
radians(dp)	dp	degrees to radians	radians(45.0)	0.785398163397448
round(dp or numeric)	(same as input)	round to nearest integer	round(42.4)	42
round(v numeric, s int)	numeric	round to s decimal places	round(42.4382, 2)	42.44
sign(dp or numeric)	(same as input)	sign of the argument (-1, 0, +1)	sign(-8.4)	-1
sqrt(dp or numeric)	(same as input)	square root	sqrt(2.0)	1.4142135623731
trunc(dp or numeric)	(same as input)	truncate toward zero	trunc(42.8)	42
trunc(v numeric, s int)	numeric	truncate to s decimal places	trunc(42.4382, 2)	42.43
width_bucket(op numeric, b1 numeric, b2 numeric, count int)	int	return the bucket to which operand would be assigned in an equidepth histogram with count buckets, in the range b1 to b2	width_bucket(5.35, 0.024, 10.06, 5)	

Function	Return Type	Description	Example	Result
`width_bucket(op dp, b1 dp, b2 dp, count int)`	`int`	return the bucket to which `operand` would be assigned in an equidepth histogram with `count` buckets, in the range `b1` to `b2`	`width_bucket(5.35, 0.024, 10.06, 5)`	

Table 9-4 shows functions for generating random numbers.

Table 9-4. Random Functions

Function	Return Type	Description
`random()`	`dp`	random value in the range 0.0 <= x < 1.0
`setseed(dp)`	`void`	set seed for subsequent `random()` calls (value between -1.0 and 1.0, inclusive)

The characteristics of the values returned by `random()` depend on the system implementation. It is not suitable for cryptographic applications; see pgcrypto module for an alternative.

Finally, Table 9-5 shows the available trigonometric functions. All trigonometric functions take arguments and return values of type `double precision`. Trigonometric functions arguments are expressed in radians. Inverse functions return values are expressed in radians. See unit transformation functions `radians()` and `degrees()` above.

Table 9-5. Trigonometric Functions

Function	Description
`acos(x)`	inverse cosine
`asin(x)`	inverse sine
`atan(x)`	inverse tangent
`atan2(y, x)`	inverse tangent of `y/x`
`cos(x)`	cosine
`cot(x)`	cotangent
`sin(x)`	sine
`tan(x)`	tangent

9.4. String Functions and Operators

This section describes functions and operators for examining and manipulating string values. Strings in this context include values of the types `character`, `character varying`, and `text`. Unless otherwise noted, all of the functions listed below work on all of these types, but be wary of potential effects of automatic space-padding when using the `character` type. Some functions also exist natively for the bit-string types.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9-6. PostgreSQL also provides versions of these functions that use the regular function invocation syntax (see Table 9-7).

> **Note:** Before PostgreSQL 8.3, these functions would silently accept values of several non-string data types as well, due to the presence of implicit coercions from those data types to `text`. Those coercions have been removed because they frequently caused surprising behaviors. However, the string concatenation operator (`||`) still accepts non-string input, so long as at least one input is of a string type, as shown in Table 9-6. For other cases, insert an explicit coercion to `text` if you need to duplicate the previous behavior.

Table 9-6. SQL String Functions and Operators

Function	Return Type	Description	Example	Result
`string || string`	`text`	String concatenation	`'Post' || 'greSQL'`	`PostgreSQL`
`string || non-string` or `non-string || string`	`text`	String concatenation with one non-string input	`'Value: ' || 42`	`Value: 42`
`bit_length(string)`	`int`	Number of bits in string	`bit_length('jose')`	`32`
`char_length(string)` or `character_length(string)`	`int`	Number of characters in string	`char_length('jose')`	`4`
`lower(string)`	`text`	Convert string to lower case	`lower('TOM')`	`tom`
`octet_length(string)`	`int`	Number of bytes in string	`octet_length('jose')`	`4`
`overlay(string placing string from int [for int])`	`text`	Replace substring	`overlay('Txxxxas' placing 'hom' from 2 for 4)`	`Thomas`
`position(substring in string)`	`int`	Location of specified substring	`position('om' in 'Thomas')`	`3`
`substring(string [from int] [for int])`	`text`	Extract substring	`substring('Thomas' from 2 for 3)`	`hom`

Function	Return Type	Description	Example	Result
substring(string from *pattern*)	text	Extract substring matching POSIX regular expression. See Section 9.7 for more information on pattern matching.	substring('Thomas' from '...$')	mas
substring(string from *pattern* for *escape*)	text	Extract substring matching SQL regular expression. See Section 9.7 for more information on pattern matching.	substring('Thomas' from '%#"o_a#"_' for '#')	oma
trim([leading | trailing | both] [characters] from string)	text	Remove the longest string containing only the characters (a space by default) from the start/end/both ends of the string	trim(both 'x' from 'xTomxx')	Tom
trim([leading | trailing | both] [from] string [, characters])	text	Non-standard version of trim()	trim(both from 'xTomxx', 'x')	Tom
upper(string)	text	Convert string to upper case	upper('tom')	TOM

Additional string manipulation functions are available and are listed in Table 9-7. Some of them are used internally to implement the SQL-standard string functions listed in Table 9-6.

Table 9-7. Other String Functions

Function	Return Type	Description	Example	Result

Function	Return Type	Description	Example	Result
ascii(string)	int	ASCII code of the first character of the argument. For UTF8 returns the Unicode code point of the character. For other multibyte encodings, the argument must be an ASCII character.	ascii('x')	120
btrim(string text [, characters text])	text	Remove the longest string consisting only of characters in characters (a space by default) from the start and end of string	btrim('xyxtrimyyx', 'xy')	trim
chr(int)	text	Character with the given code. For UTF8 the argument is treated as a Unicode code point. For other multibyte encodings the argument must designate an ASCII character. The NULL (0) character is not allowed because text data types cannot store such bytes.	chr(65)	A
concat(str "any" [, str "any" [, ...]])	text	Concatenate the text representations of all the arguments. NULL arguments are ignored.	concat('abcde', 2, NULL, 22)	abcde222

Function	Return Type	Description	Example	Result
concat_ws(sep text, str "any" [, str "any" [, ...]])	text	Concatenate all but the first argument with separators. The first argument is used as the separator string. NULL arguments are ignored.	concat_ws(',', 'abcde', 2, NULL, 22)	abcde,2,22
convert(string bytea, src_encoding name, dest_encoding name)	bytea	Convert string to dest_encoding. The original encoding is specified by src_encoding. The string must be valid in this encoding. Conversions can be defined by CREATE CONVERSION. Also there are some predefined conversions. See Table 9-8 for available conversions.	convert('text_in_utf8', 'UTF8', 'LATIN1')	text_in_utf8 represented in Latin-1 encoding (ISO 8859-1)
convert_from(string bytea, src_encoding name)	text	Convert string to the database encoding. The original encoding is specified by src_encoding. The string must be valid in this encoding.	convert_from('text_in_utf8', 'UTF8')	text_in_utf8 represented in the current database encoding
convert_to(string text, dest_encoding name)	bytea	Convert string to dest_encoding.	convert_to('some text', 'UTF8')	some text represented in the UTF8 encoding
decode(string text, format text)	bytea	Decode binary data from textual representation in string. Options for format are same as in encode.	decode('MTIzAAE=', 'base64')	132330001

Function	Return Type	Description	Example	Result
encode(data bytea, format text)	text	Encode binary data into a textual representation. Supported formats are: base64, hex, escape. escape converts zero bytes and high-bit-set bytes to octal sequences (\nnn) and doubles backslashes.	encode(E'123\\000\001', 'base64')	MTIzAAE=
format(formatstr text [, formatarg "any" [, ...]])	text	Format arguments according to a format string. This function is similar to the C function sprintf. See Section 9.4.1.	format('Hello %s, %1$s', 'World')	Hello World, World
initcap(string)	text	Convert the first letter of each word to upper case and the rest to lower case. Words are sequences of alphanumeric characters separated by non-alphanumeric characters.	initcap('hi THOMAS')	Hi Thomas
left(str text, n int)	text	Return first *n* characters in the string. When *n* is negative, return all but last |*n*| characters.	left('abcde', 2)	ab
length(string)	int	Number of characters in string	length('jose')	4
length(string bytea, encoding name)	int	Number of characters in string in the given encoding. The string must be valid in this encoding.	length('jose', 'UTF8')	4

Function	Return Type	Description	Example	Result
lpad(string text, length int [, fill text])	text	Fill up the string to length length by prepending the characters fill (a space by default). If the string is already longer than length then it is truncated (on the right).	lpad('hi', 5, 'xy')	xyxhi
ltrim(string text [, characters text])	text	Remove the longest string containing only characters from characters (a space by default) from the start of string	ltrim('zzzytrim', 'xyz')	trim
md5(string)	text	Calculates the MD5 hash of string, returning the result in hexadecimal	md5('abc')	900150983cd24fb0d6963f7d28e17f72
pg_client_encoding()	name	Current client encoding name	pg_client_encoding()	SQL_ASCII
quote_ident(string text)	text	Return the given string suitably quoted to be used as an identifier in an SQL statement string. Quotes are added only if necessary (i.e., if the string contains non-identifier characters or would be case-folded). Embedded quotes are properly doubled. See also Example 40-1.	quote_ident('Foo bar')	"Foo bar"

Function	Return Type	Description	Example	Result
`quote_literal(string text)`	`text`	Return the given string suitably quoted to be used as a string literal in an SQL statement string. Embedded single-quotes and backslashes are properly doubled. Note that `quote_literal` returns null on null input; if the argument might be null, `quote_nullable` is often more suitable. See also Example 40-1.	`quote_literal(E'O\'Reilly')`	`E'O''Reilly'`
`quote_literal(value anyelement)`	`text`	Coerce the given value to text and then quote it as a literal. Embedded single-quotes and backslashes are properly doubled.	`quote_literal(42.5)`	`'42.5'`
`quote_nullable(string text)`	`text`	Return the given string suitably quoted to be used as a string literal in an SQL statement string; or, if the argument is null, return `NULL`. Embedded single-quotes and backslashes are properly doubled. See also Example 40-1.	`quote_nullable(NULL)`	`NULL`

Function	Return Type	Description	Example	Result
quote_nullable(value anyelement)	text	Coerce the given value to text and then quote it as a literal; or, if the argument is null, return NULL. Embedded single-quotes and backslashes are properly doubled.	quote_nullable(42.5)	'42.5'
regexp_matches(string text, pattern text [, flags text])	setof text[]	Return all captured substrings resulting from matching a POSIX regular expression against the string. See Section 9.7.3 for more information.	regexp_matches('foobarbequebaz', '(bar)(beque)')	{bar,beque}
regexp_replace(string text, pattern text, replacement text [, flags text])	text	Replace substring(s) matching a POSIX regular expression. See Section 9.7.3 for more information.	regexp_replace('Thomas', '.[mN]a.', 'M')	ThM
regexp_split_to_array(string text, pattern text [, flags text])	text[]	Split string using a POSIX regular expression as the delimiter. See Section 9.7.3 for more information.	regexp_split_to_array('hello world', E'\\s+')	{hello,world}
regexp_split_to_table(string text, pattern text [, flags text])	setof text	Split string using a POSIX regular expression as the delimiter. See Section 9.7.3 for more information.	regexp_split_to_table('hello world', E'\\s+')	hello world (2 rows)
repeat(string text, number int)	text	Repeat string the specified number of times	repeat('Pg', 4)	PgPgPgPg

Function	Return Type	Description	Example	Result
`replace(string text, from text, to text)`	`text`	Replace all occurrences in `string` of substring `from` with substring `to`	`replace('abcdefabcdef', 'cd', 'XX')`	`abXXefabXXef`
`reverse(str)`	`text`	Return reversed string.	`reverse('abcde')`	`edcba`
`right(str text, n int)`	`text`	Return last *n* characters in the string. When *n* is negative, return all but first |*n*| characters.	`right('abcde', 2)`	`de`
`rpad(string text, length int [, fill text])`	`text`	Fill up the `string` to length `length` by appending the characters `fill` (a space by default). If the `string` is already longer than `length` then it is truncated.	`rpad('hi', 5, 'xy')`	`hixyx`
`rtrim(string text [, characters text])`	`text`	Remove the longest string containing only characters from `characters` (a space by default) from the end of `string`	`rtrim('trimxxxxx', 'x')`	`trim`
`split_part(string text, delimiter text, field int)`	`text`	Split `string` on `delimiter` and return the given field (counting from one)	`split_part('abc~@~def~@~ghi', '~@~', 2)`	`def`
`strpos(string, substring)`	`int`	Location of specified substring (same as `position(substring in string)`, but note the reversed argument order)	`strpos('high', 'ig')`	`2`
`substr(string, from [, count])`	`text`	Extract substring (same as `substring(string from from for count)`)	`substr('alphabet', 3, 2)`	`ph`

Function	Return Type	Description	Example	Result
to_ascii(string text [, encoding text])	text	Convert string to ASCII from another encoding (only supports conversion from LATIN1, LATIN2, LATIN9, and WIN1250 encodings)	to_ascii('Karel')	Karel
to_hex(number int or bigint)	text	Convert number to its equivalent hexadecimal representation	to_hex(2147483647)	7fffffff
translate(string text, from text, to text)	text	Any character in string that matches a character in the from set is replaced by the corresponding character in the to set. If from is longer than to, occurrences of the extra characters in from are removed.	translate('12345', '143', 'ax')	a2x5

The concat, concat_ws and format functions are variadic, so it is possible to pass the values to be concatenated or formatted as an array marked with the VARIADIC keyword (see Section 35.4.5). The array's elements are treated as if they were separate ordinary arguments to the function. If the variadic array argument is NULL, concat and concat_ws return NULL, but format treats a NULL as a zero-element array.

See also the aggregate function string_agg in Section 9.20.

Table 9-8. Built-in Conversions

Conversion Name [a]	Source Encoding	Destination Encoding
ascii_to_mic	SQL_ASCII	MULE_INTERNAL
ascii_to_utf8	SQL_ASCII	UTF8
big5_to_euc_tw	BIG5	EUC_TW
big5_to_mic	BIG5	MULE_INTERNAL
big5_to_utf8	BIG5	UTF8
euc_cn_to_mic	EUC_CN	MULE_INTERNAL
euc_cn_to_utf8	EUC_CN	UTF8
euc_jp_to_mic	EUC_JP	MULE_INTERNAL
euc_jp_to_sjis	EUC_JP	SJIS

Conversion Name [a]	Source Encoding	Destination Encoding
euc_jp_to_utf8	EUC_JP	UTF8
euc_kr_to_mic	EUC_KR	MULE_INTERNAL
euc_kr_to_utf8	EUC_KR	UTF8
euc_tw_to_big5	EUC_TW	BIG5
euc_tw_to_mic	EUC_TW	MULE_INTERNAL
euc_tw_to_utf8	EUC_TW	UTF8
gb18030_to_utf8	GB18030	UTF8
gbk_to_utf8	GBK	UTF8
iso_8859_10_to_utf8	LATIN6	UTF8
iso_8859_13_to_utf8	LATIN7	UTF8
iso_8859_14_to_utf8	LATIN8	UTF8
iso_8859_15_to_utf8	LATIN9	UTF8
iso_8859_16_to_utf8	LATIN10	UTF8
iso_8859_1_to_mic	LATIN1	MULE_INTERNAL
iso_8859_1_to_utf8	LATIN1	UTF8
iso_8859_2_to_mic	LATIN2	MULE_INTERNAL
iso_8859_2_to_utf8	LATIN2	UTF8
iso_8859_2_to_windows_1250	LATIN2	WIN1250
iso_8859_3_to_mic	LATIN3	MULE_INTERNAL
iso_8859_3_to_utf8	LATIN3	UTF8
iso_8859_4_to_mic	LATIN4	MULE_INTERNAL
iso_8859_4_to_utf8	LATIN4	UTF8
iso_8859_5_to_koi8_r	ISO_8859_5	KOI8R
iso_8859_5_to_mic	ISO_8859_5	MULE_INTERNAL
iso_8859_5_to_utf8	ISO_8859_5	UTF8
iso_8859_5_to_windows_1251	ISO_8859_5	WIN1251
iso_8859_5_to_windows_866	ISO_8859_5	WIN866
iso_8859_6_to_utf8	ISO_8859_6	UTF8
iso_8859_7_to_utf8	ISO_8859_7	UTF8
iso_8859_8_to_utf8	ISO_8859_8	UTF8
iso_8859_9_to_utf8	LATIN5	UTF8
johab_to_utf8	JOHAB	UTF8
koi8_r_to_iso_8859_5	KOI8R	ISO_8859_5
koi8_r_to_mic	KOI8R	MULE_INTERNAL
koi8_r_to_utf8	KOI8R	UTF8
koi8_r_to_windows_1251	KOI8R	WIN1251
koi8_r_to_windows_866	KOI8R	WIN866
koi8_u_to_utf8	KOI8U	UTF8
mic_to_ascii	MULE_INTERNAL	SQL_ASCII

Conversion Name [a]	Source Encoding	Destination Encoding
mic_to_big5	MULE_INTERNAL	BIG5
mic_to_euc_cn	MULE_INTERNAL	EUC_CN
mic_to_euc_jp	MULE_INTERNAL	EUC_JP
mic_to_euc_kr	MULE_INTERNAL	EUC_KR
mic_to_euc_tw	MULE_INTERNAL	EUC_TW
mic_to_iso_8859_1	MULE_INTERNAL	LATIN1
mic_to_iso_8859_2	MULE_INTERNAL	LATIN2
mic_to_iso_8859_3	MULE_INTERNAL	LATIN3
mic_to_iso_8859_4	MULE_INTERNAL	LATIN4
mic_to_iso_8859_5	MULE_INTERNAL	ISO_8859_5
mic_to_koi8_r	MULE_INTERNAL	KOI8R
mic_to_sjis	MULE_INTERNAL	SJIS
mic_to_windows_1250	MULE_INTERNAL	WIN1250
mic_to_windows_1251	MULE_INTERNAL	WIN1251
mic_to_windows_866	MULE_INTERNAL	WIN866
sjis_to_euc_jp	SJIS	EUC_JP
sjis_to_mic	SJIS	MULE_INTERNAL
sjis_to_utf8	SJIS	UTF8
tcvn_to_utf8	WIN1258	UTF8
uhc_to_utf8	UHC	UTF8
utf8_to_ascii	UTF8	SQL_ASCII
utf8_to_big5	UTF8	BIG5
utf8_to_euc_cn	UTF8	EUC_CN
utf8_to_euc_jp	UTF8	EUC_JP
utf8_to_euc_kr	UTF8	EUC_KR
utf8_to_euc_tw	UTF8	EUC_TW
utf8_to_gb18030	UTF8	GB18030
utf8_to_gbk	UTF8	GBK
utf8_to_iso_8859_1	UTF8	LATIN1
utf8_to_iso_8859_10	UTF8	LATIN6
utf8_to_iso_8859_13	UTF8	LATIN7
utf8_to_iso_8859_14	UTF8	LATIN8
utf8_to_iso_8859_15	UTF8	LATIN9
utf8_to_iso_8859_16	UTF8	LATIN10
utf8_to_iso_8859_2	UTF8	LATIN2
utf8_to_iso_8859_3	UTF8	LATIN3
utf8_to_iso_8859_4	UTF8	LATIN4
utf8_to_iso_8859_5	UTF8	ISO_8859_5
utf8_to_iso_8859_6	UTF8	ISO_8859_6
utf8_to_iso_8859_7	UTF8	ISO_8859_7
utf8_to_iso_8859_8	UTF8	ISO_8859_8
utf8_to_iso_8859_9	UTF8	LATIN5

Conversion Name [a]	Source Encoding	Destination Encoding
utf8_to_johab	UTF8	JOHAB
utf8_to_koi8_r	UTF8	KOI8R
utf8_to_koi8_u	UTF8	KOI8U
utf8_to_sjis	UTF8	SJIS
utf8_to_tcvn	UTF8	WIN1258
utf8_to_uhc	UTF8	UHC
utf8_to_windows_1250	UTF8	WIN1250
utf8_to_windows_1251	UTF8	WIN1251
utf8_to_windows_1252	UTF8	WIN1252
utf8_to_windows_1253	UTF8	WIN1253
utf8_to_windows_1254	UTF8	WIN1254
utf8_to_windows_1255	UTF8	WIN1255
utf8_to_windows_1256	UTF8	WIN1256
utf8_to_windows_1257	UTF8	WIN1257
utf8_to_windows_866	UTF8	WIN866
utf8_to_windows_874	UTF8	WIN874
windows_1250_to_iso_8859_2	WIN1250	LATIN2
windows_1250_to_mic	WIN1250	MULE_INTERNAL
windows_1250_to_utf8	WIN1250	UTF8
windows_1251_to_iso_8859_5	WIN1251	ISO_8859_5
windows_1251_to_koi8_r	WIN1251	KOI8R
windows_1251_to_mic	WIN1251	MULE_INTERNAL
windows_1251_to_utf8	WIN1251	UTF8
windows_1251_to_windows_866	WIN1251	WIN866
windows_1252_to_utf8	WIN1252	UTF8
windows_1256_to_utf8	WIN1256	UTF8
windows_866_to_iso_8859_5	WIN866	ISO_8859_5
windows_866_to_koi8_r	WIN866	KOI8R
windows_866_to_mic	WIN866	MULE_INTERNAL
windows_866_to_utf8	WIN866	UTF8
windows_866_to_windows_1251	WIN866	WIN
windows_874_to_utf8	WIN874	UTF8
euc_jis_2004_to_utf8	EUC_JIS_2004	UTF8
utf8_to_euc_jis_2004	UTF8	EUC_JIS_2004
shift_jis_2004_to_utf8	SHIFT_JIS_2004	UTF8
utf8_to_shift_jis_2004	UTF8	SHIFT_JIS_2004
euc_jis_2004_to_shift_jis_2004	EUC_JIS_2004	SHIFT_JIS_2004

Conversion Name [a]	Source Encoding	Destination Encoding
shift_jis_2004_to_euc_jis_2004	SHIFT_JIS_2004	EUC_JIS_2004

Notes:
a. The conversion names follow a standard naming scheme: The official name of the source encoding with all non-alphanumeric characters replaced by underscores, followed by _to_, followed by the similarly processed destination encoding name. Therefore, the names might deviate from the customary encoding names.

9.4.1. format

The function format produces output formatted according to a format string, in a style similar to the C function sprintf.

```
format(formatstr text [, formatarg "any" [, ...] ])
```

formatstr is a format string that specifies how the result should be formatted. Text in the format string is copied directly to the result, except where *format specifiers* are used. Format specifiers act as placeholders in the string, defining how subsequent function arguments should be formatted and inserted into the result. Each *formatarg* argument is converted to text according to the usual output rules for its data type, and then formatted and inserted into the result string according to the format specifier(s).

Format specifiers are introduced by a % character and have the form

```
%[position][flags][width]type
```

where the component fields are:

position (optional)

A string of the form *n*$ where *n* is the index of the argument to print. Index 1 means the first argument after *formatstr*. If the *position* is omitted, the default is to use the next argument in sequence.

flags (optional)

Additional options controlling how the format specifier's output is formatted. Currently the only supported flag is a minus sign (-) which will cause the format specifier's output to be left-justified. This has no effect unless the *width* field is also specified.

width (optional)

Specifies the *minimum* number of characters to use to display the format specifier's output. The output is padded on the left or right (depending on the - flag) with spaces as needed to fill the width. A too-small width does not cause truncation of the output, but is simply ignored. The width may be specified using any of the following: a positive integer; an asterisk (*) to use the next function argument as the width; or a string of the form *n*$ to use the *n*th function argument as the width.

If the width comes from a function argument, that argument is consumed before the argument that is used for the format specifier's value. If the width argument is negative, the result is left aligned (as if the - flag had been specified) within a field of length abs(*width*).

type (required)

The type of format conversion to use to produce the format specifier's output. The following types are supported:

- `s` formats the argument value as a simple string. A null value is treated as an empty string.
- `I` treats the argument value as an SQL identifier, double-quoting it if necessary. It is an error for the value to be null.
- `L` quotes the argument value as an SQL literal. A null value is displayed as the string `NULL`, without quotes.

In addition to the format specifiers described above, the special sequence `%%` may be used to output a literal `%` character.

Here are some examples of the basic format conversions:

```
SELECT format('Hello %s', 'World');
Result: Hello World

SELECT format('Testing %s, %s, %s, %%', 'one', 'two', 'three');
Result: Testing one, two, three, %

SELECT format('INSERT INTO %I VALUES(%L)', 'Foo bar', E'O\'Reilly');
Result: INSERT INTO "Foo bar" VALUES('O''Reilly')

SELECT format('INSERT INTO %I VALUES(%L)', 'locations', E'C:\\Program Files');
Result: INSERT INTO locations VALUES(E'C:\\Program Files')
```

Here are examples using *width* fields and the - flag:

```
SELECT format('|%10s|', 'foo');
Result: |       foo|

SELECT format('|%-10s|', 'foo');
Result: |foo       |

SELECT format('|%*s|', 10, 'foo');
Result: |       foo|

SELECT format('|%*s|', -10, 'foo');
Result: |foo       |

SELECT format('|%-*s|', 10, 'foo');
Result: |foo       |

SELECT format('|%-*s|', -10, 'foo');
Result: |foo       |
```

These examples show use of *position* fields:

```
SELECT format('Testing %3$s, %2$s, %1$s', 'one', 'two', 'three');
Result: Testing three, two, one
```

```
SELECT format('|%*2$s|', 'foo', 10, 'bar');
Result: |       bar|

SELECT format('|%1$*2$s|', 'foo', 10, 'bar');
Result: |       foo|
```

Unlike the standard C function `sprintf`, PostgreSQL's `format` function allows format specifiers with and without *position* fields to be mixed in the same format string. A format specifier without a *position* field always uses the next argument after the last argument consumed. In addition, the `format` function does not require all function arguments to be used in the format string. For example:

```
SELECT format('Testing %3$s, %2$s, %s', 'one', 'two', 'three');
Result: Testing three, two, three
```

The `%I` and `%L` format specifiers are particularly useful for safely constructing dynamic SQL statements. See Example 40-1.

9.5. Binary String Functions and Operators

This section describes functions and operators for examining and manipulating values of type `bytea`.

SQL defines some string functions that use key words, rather than commas, to separate arguments. Details are in Table 9-9. PostgreSQL also provides versions of these functions that use the regular function invocation syntax (see Table 9-10).

> **Note:** The sample results shown on this page assume that the server parameter `bytea_output` is set to `escape` (the traditional PostgreSQL format).

Table 9-9. SQL Binary String Functions and Operators

Function	Return Type	Description	Example	Result
`string || string`	`bytea`	String concatenation	`E'\\\\Post'::bytea || E'\\047gres\\000'::bytea`	`\\Post'gres\000`
`octet_length(string)`	`int`	Number of bytes in binary string	`octet_length(E'jo\\000se'::bytea)`	`5`
`overlay(string placing string from int [for int])`	`bytea`	Replace substring	`overlay(E'Th\\000omas'::bytea placing E'\\002\\003'::bytea from 2 for 3)`	`T\000\002\003mas`

Function	Return Type	Description	Example	Result
position(substring in string)	int	Location of specified substring	position(E'\\000om'::bytea in E'Th\\000omas'::bytea)	3
substring(string [from int] [for int])	bytea	Extract substring	substring(E'Th\\000omas'::bytea from 2 for 3)	h\000o
trim([both] bytes from string)	bytea	Remove the longest string containing only the bytes in bytes from the start and end of string	trim(E'\\000'::bytea from E'\\000Tom\\000'::bytea)	Tom

Additional binary string manipulation functions are available and are listed in Table 9-10. Some of them are used internally to implement the SQL-standard string functions listed in Table 9-9.

Table 9-10. Other Binary String Functions

Function	Return Type	Description	Example	Result
btrim(string bytea, bytes bytea)	bytea	Remove the longest string consisting only of bytes in bytes from the start and end of string	btrim(E'\\000trim\\000'::bytea, E'\\000'::bytea)	trim
decode(string text, format text)	bytea	Decode binary data from textual representation in string. Options for format are same as in encode.	decode(E'123\\000456', 'escape')	123\000456
encode(data bytea, format text)	text	Encode binary data into a textual representation. Supported formats are: base64, hex, escape. escape converts zero bytes and high-bit-set bytes to octal sequences (*nnn*) and doubles backslashes.	encode(E'123\\000456'::bytea, 'escape')	123\000456

Function	Return Type	Description	Example	Result
get_bit(string, offset)	int	Extract bit from string	get_bit(E'Th\\000omas'::bytea, 45)	1
get_byte(string, offset)	int	Extract byte from string	get_byte(E'Th\\000omas'::bytea, 4)	109
length(string)	int	Length of binary string	length(E'jo\\000se'::bytea)	5
md5(string)	text	Calculates the MD5 hash of string, returning the result in hexadecimal	md5(E'Th\\000omas'::bytea)	8ab2d3f9689aaf18b4958c334c82d8b1
set_bit(string, offset, newvalue)	bytea	Set bit in string	set_bit(E'Th\\000omas'::bytea, 45, 0)	Th\000omAs
set_byte(string, offset, newvalue)	bytea	Set byte in string	set_byte(E'Th\\000omas'::bytea, 4, 64)	Th\000o@as

get_byte and set_byte number the first byte of a binary string as byte 0. get_bit and set_bit number bits from the right within each byte; for example bit 0 is the least significant bit of the first byte, and bit 15 is the most significant bit of the second byte.

See also the aggregate function string_agg in Section 9.20 and the large object functions in Section 32.4.

9.6. Bit String Functions and Operators

This section describes functions and operators for examining and manipulating bit strings, that is values of the types bit and bit varying. Aside from the usual comparison operators, the operators shown in Table 9-11 can be used. Bit string operands of &, |, and # must be of equal length. When bit shifting, the original length of the string is preserved, as shown in the examples.

Table 9-11. Bit String Operators

Operator	Description	Example	Result
||	concatenation	B'10001' || B'011'	10001011
&	bitwise AND	B'10001' & B'01101'	00001
|	bitwise OR	B'10001' | B'01101'	11101
#	bitwise XOR	B'10001' # B'01101'	11100
~	bitwise NOT	~ B'10001'	01110
<<	bitwise shift left	B'10001' << 3	01000

Operator	Description	Example	Result
>>	bitwise shift right	B'10001' >> 2	00100

The following SQL-standard functions work on bit strings as well as character strings: length, bit_length, octet_length, position, substring, overlay.

The following functions work on bit strings as well as binary strings: get_bit, set_bit. When working with a bit string, these functions number the first (leftmost) bit of the string as bit 0.

In addition, it is possible to cast integral values to and from type bit. Some examples:

```
44::bit(10)                    0000101100
44::bit(3)                     100
cast(-44 as bit(12))           111111010100
'1110'::bit(4)::integer        14
```

Note that casting to just "bit" means casting to bit(1), and so will deliver only the least significant bit of the integer.

> **Note:** Casting an integer to bit(n) copies the rightmost n bits. Casting an integer to a bit string width wider than the integer itself will sign-extend on the left.

9.7. Pattern Matching

There are three separate approaches to pattern matching provided by PostgreSQL: the traditional SQL LIKE operator, the more recent SIMILAR TO operator (added in SQL:1999), and POSIX-style regular expressions. Aside from the basic "does this string match this pattern?" operators, functions are available to extract or replace matching substrings and to split a string at matching locations.

> **Tip:** If you have pattern matching needs that go beyond this, consider writing a user-defined function in Perl or Tcl.

9.7.1. LIKE

```
string LIKE pattern [ESCAPE escape-character]
string NOT LIKE pattern [ESCAPE escape-character]
```

The LIKE expression returns true if the *string* matches the supplied *pattern*. (As expected, the NOT LIKE expression returns false if LIKE returns true, and vice versa. An equivalent expression is NOT (*string* LIKE *pattern*).)

If *pattern* does not contain percent signs or underscores, then the pattern only represents the string itself; in that case LIKE acts like the equals operator. An underscore (_) in *pattern* stands for (matches) any single character; a percent sign (%) matches any sequence of zero or more characters.

Some examples:

```
'abc' LIKE 'abc'    true
'abc' LIKE 'a%'     true
'abc' LIKE '_b_'    true
```

```
'abc' LIKE 'c'      false
```

LIKE pattern matching always covers the entire string. Therefore, if it's desired to match a sequence anywhere within a string, the pattern must start and end with a percent sign.

To match a literal underscore or percent sign without matching other characters, the respective character in *pattern* must be preceded by the escape character. The default escape character is the backslash but a different one can be selected by using the ESCAPE clause. To match the escape character itself, write two escape characters.

> **Note:** If you have standard_conforming_strings turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

It's also possible to select no escape character by writing ESCAPE ''. This effectively disables the escape mechanism, which makes it impossible to turn off the special meaning of underscore and percent signs in the pattern.

The key word ILIKE can be used instead of LIKE to make the match case-insensitive according to the active locale. This is not in the SQL standard but is a PostgreSQL extension.

The operator ~~ is equivalent to LIKE, and ~~* corresponds to ILIKE. There are also !~~ and !~~* operators that represent NOT LIKE and NOT ILIKE, respectively. All of these operators are PostgreSQL-specific.

9.7.2. SIMILAR TO Regular Expressions

```
string SIMILAR TO pattern [ESCAPE escape-character]
string NOT SIMILAR TO pattern [ESCAPE escape-character]
```

The SIMILAR TO operator returns true or false depending on whether its pattern matches the given string. It is similar to LIKE, except that it interprets the pattern using the SQL standard's definition of a regular expression. SQL regular expressions are a curious cross between LIKE notation and common regular expression notation.

Like LIKE, the SIMILAR TO operator succeeds only if its pattern matches the entire string; this is unlike common regular expression behavior where the pattern can match any part of the string. Also like LIKE, SIMILAR TO uses _ and % as wildcard characters denoting any single character and any string, respectively (these are comparable to . and .* in POSIX regular expressions).

In addition to these facilities borrowed from LIKE, SIMILAR TO supports these pattern-matching metacharacters borrowed from POSIX regular expressions:

- | denotes alternation (either of two alternatives).
- * denotes repetition of the previous item zero or more times.
- + denotes repetition of the previous item one or more times.
- ? denotes repetition of the previous item zero or one time.
- {*m*} denotes repetition of the previous item exactly *m* times.
- {*m*,} denotes repetition of the previous item *m* or more times.
- {*m*,*n*} denotes repetition of the previous item at least *m* and not more than *n* times.

- Parentheses `()` can be used to group items into a single logical item.
- A bracket expression `[...]` specifies a character class, just as in POSIX regular expressions.

Notice that the period (`.`) is not a metacharacter for `SIMILAR TO`.

As with `LIKE`, a backslash disables the special meaning of any of these metacharacters; or a different escape character can be specified with `ESCAPE`.

Some examples:

```
'abc' SIMILAR TO 'abc'      true
'abc' SIMILAR TO 'a'        false
'abc' SIMILAR TO '%(b|d)%'  true
'abc' SIMILAR TO '(b|c)%'   false
```

The `substring` function with three parameters, `substring(`*`string`* `from` *`pattern`* `for` *`escape-character`*`)`, provides extraction of a substring that matches an SQL regular expression pattern. As with `SIMILAR TO`, the specified pattern must match the entire data string, or else the function fails and returns null. To indicate the part of the pattern that should be returned on success, the pattern must contain two occurrences of the escape character followed by a double quote (`"`). The text matching the portion of the pattern between these markers is returned.

Some examples, with `#"` delimiting the return string:

```
substring('foobar' from '%#"o_b#"%' for '#')   oob
substring('foobar' from '#"o_b#"%' for '#')    NULL
```

9.7.3. POSIX Regular Expressions

Table 9-12 lists the available operators for pattern matching using POSIX regular expressions.

Table 9-12. Regular Expression Match Operators

Operator	Description	Example
`~`	Matches regular expression, case sensitive	`'thomas' ~ '.*thomas.*'`
`~*`	Matches regular expression, case insensitive	`'thomas' ~* '.*Thomas.*'`
`!~`	Does not match regular expression, case sensitive	`'thomas' !~ '.*Thomas.*'`
`!~*`	Does not match regular expression, case insensitive	`'thomas' !~* '.*vadim.*'`

POSIX regular expressions provide a more powerful means for pattern matching than the `LIKE` and `SIMILAR TO` operators. Many Unix tools such as `egrep`, `sed`, or `awk` use a pattern matching language that is similar to the one described here.

A regular expression is a character sequence that is an abbreviated definition of a set of strings (a *regular set*). A string is said to match a regular expression if it is a member of the regular set described by the regular expression. As with `LIKE`, pattern characters match string characters exactly unless they are special characters in the regular expression language — but regular expressions use different

special characters than LIKE does. Unlike LIKE patterns, a regular expression is allowed to match anywhere within a string, unless the regular expression is explicitly anchored to the beginning or end of the string.

Some examples:

```
'abc' ~ 'abc'    true
'abc' ~ '^a'     true
'abc' ~ '(b|d)'  true
'abc' ~ '^(b|c)' false
```

The POSIX pattern language is described in much greater detail below.

The substring function with two parameters, substring(*string* from *pattern*), provides extraction of a substring that matches a POSIX regular expression pattern. It returns null if there is no match, otherwise the portion of the text that matched the pattern. But if the pattern contains any parentheses, the portion of the text that matched the first parenthesized subexpression (the one whose left parenthesis comes first) is returned. You can put parentheses around the whole expression if you want to use parentheses within it without triggering this exception. If you need parentheses in the pattern before the subexpression you want to extract, see the non-capturing parentheses described below.

Some examples:

```
substring('foobar' from 'o.b')     oob
substring('foobar' from 'o(.)b')   o
```

The regexp_replace function provides substitution of new text for substrings that match POSIX regular expression patterns. It has the syntax regexp_replace(*source*, *pattern*, *replacement* [, *flags*]). The *source* string is returned unchanged if there is no match to the *pattern*. If there is a match, the *source* string is returned with the *replacement* string substituted for the matching substring. The *replacement* string can contain *n*, where *n* is 1 through 9, to indicate that the source substring matching the *n*'th parenthesized subexpression of the pattern should be inserted, and it can contain \& to indicate that the substring matching the entire pattern should be inserted. Write \\ if you need to put a literal backslash in the replacement text. The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Flag i specifies case-insensitive matching, while flag g specifies replacement of each matching substring rather than only the first one. Supported flags (though not g) are described in Table 9-20.

Some examples:

```
regexp_replace('foobarbaz', 'b..', 'X')
                                   fooXbaz
regexp_replace('foobarbaz', 'b..', 'X', 'g')
                                   fooXX
regexp_replace('foobarbaz', 'b(..)', E'X\\1Y', 'g')
                                   fooXarYXazY
```

The regexp_matches function returns a text array of all of the captured substrings resulting from matching a POSIX regular expression pattern. It has the syntax regexp_matches(*string*, *pattern* [, *flags*]). The function can return no rows, one row, or multiple rows (see the g flag below). If the *pattern* does not match, the function returns no rows. If the pattern contains no parenthesized subexpressions, then each row returned is a single-element text array containing the substring matching the

whole pattern. If the pattern contains parenthesized subexpressions, the function returns a text array whose *n*'th element is the substring matching the *n*'th parenthesized subexpression of the pattern (not counting "non-capturing" parentheses; see below for details). The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. Flag `g` causes the function to find each match in the string, not only the first one, and return a row for each such match. Supported flags (though not `g`) are described in Table 9-20.

Some examples:

```
SELECT regexp_matches('foobarbequebaz', '(bar)(beque)');
 regexp_matches
----------------
 {bar,beque}
(1 row)

SELECT regexp_matches('foobarbequebazilbarfbonk', '(b[^b]+)(b[^b]+)', 'g');
 regexp_matches
----------------
 {bar,beque}
 {bazil,barf}
(2 rows)

SELECT regexp_matches('foobarbequebaz', 'barbeque');
 regexp_matches
----------------
 {barbeque}
(1 row)
```

It is possible to force `regexp_matches()` to always return one row by using a sub-select; this is particularly useful in a `SELECT` target list when you want all rows returned, even non-matching ones:

```
SELECT col1, (SELECT regexp_matches(col2, '(bar)(beque)')) FROM tab;
```

The `regexp_split_to_table` function splits a string using a POSIX regular expression pattern as a delimiter. It has the syntax `regexp_split_to_table(`*`string`*`, `*`pattern`*` [, `*`flags`*` ])`. If there is no match to the *pattern*, the function returns the *string*. If there is at least one match, for each match it returns the text from the end of the last match (or the beginning of the string) to the beginning of the match. When there are no more matches, it returns the text from the end of the last match to the end of the string. The *flags* parameter is an optional text string containing zero or more single-letter flags that change the function's behavior. `regexp_split_to_table` supports the flags described in Table 9-20.

The `regexp_split_to_array` function behaves the same as `regexp_split_to_table`, except that `regexp_split_to_array` returns its result as an array of `text`. It has the syntax `regexp_split_to_array(`*`string`*`, `*`pattern`*` [, `*`flags`*` ])`. The parameters are the same as for `regexp_split_to_table`.

Some examples:

```
SELECT foo FROM regexp_split_to_table('the quick brown fox jumps over the lazy dog', E'\
  foo
-------
 the
 quick
```

```
 brown
 fox
 jumps
 over
 the
 lazy
 dog
(9 rows)

SELECT regexp_split_to_array('the quick brown fox jumps over the lazy dog', E'\\s+');
              regexp_split_to_array
-----------------------------------------------
 {the,quick,brown,fox,jumps,over,the,lazy,dog}
(1 row)

SELECT foo FROM regexp_split_to_table('the quick brown fox', E'\\s*') AS foo;
 foo
-----
 t
 h
 e
 q
 u
 i
 c
 k
 b
 r
 o
 w
 n
 f
 o
 x
(16 rows)
```

As the last example demonstrates, the regexp split functions ignore zero-length matches that occur at the start or end of the string or immediately after a previous match. This is contrary to the strict definition of regexp matching that is implemented by `regexp_matches`, but is usually the most convenient behavior in practice. Other software systems such as Perl use similar definitions.

9.7.3.1. Regular Expression Details

PostgreSQL's regular expressions are implemented using a software package written by Henry Spencer. Much of the description of regular expressions below is copied verbatim from his manual.

Regular expressions (REs), as defined in POSIX 1003.2, come in two forms: *extended* REs or EREs (roughly those of `egrep`), and *basic* REs or BREs (roughly those of `ed`). PostgreSQL supports both forms, and also implements some extensions that are not in the POSIX standard, but have become widely used due to their availability in programming languages such as Perl and Tcl. REs using these non-POSIX extensions are called *advanced* REs or AREs in this documentation. AREs are almost an exact superset of EREs, but BREs have several notational incompatibilities (as well as being much more limited). We first describe the ARE and ERE forms, noting features that apply only to AREs, and then describe how BREs differ.

Note: PostgreSQL always initially presumes that a regular expression follows the ARE rules. However, the more limited ERE or BRE rules can be chosen by prepending an *embedded option* to the RE pattern, as described in Section 9.7.3.4. This can be useful for compatibility with applications that expect exactly the POSIX 1003.2 rules.

A regular expression is defined as one or more *branches*, separated by `|`. It matches anything that matches one of the branches.

A branch is zero or more *quantified atoms* or *constraints*, concatenated. It matches a match for the first, followed by a match for the second, etc; an empty branch matches the empty string.

A quantified atom is an *atom* possibly followed by a single *quantifier*. Without a quantifier, it matches a match for the atom. With a quantifier, it can match some number of matches of the atom. An *atom* can be any of the possibilities shown in Table 9-13. The possible quantifiers and their meanings are shown in Table 9-14.

A *constraint* matches an empty string, but matches only when specific conditions are met. A constraint can be used where an atom could be used, except it cannot be followed by a quantifier. The simple constraints are shown in Table 9-15; some more constraints are described later.

Table 9-13. Regular Expression Atoms

Atom	Description
`(re)`	(where `re` is any regular expression) matches a match for `re`, with the match noted for possible reporting
`(?:re)`	as above, but the match is not noted for reporting (a "non-capturing" set of parentheses) (AREs only)
.	matches any single character
`[chars]`	a *bracket expression*, matching any one of the `chars` (see Section 9.7.3.2 for more detail)
`\k`	(where `k` is a non-alphanumeric character) matches that character taken as an ordinary character, e.g., `\\` matches a backslash character
`\c`	where `c` is alphanumeric (possibly followed by other characters) is an *escape*, see Section 9.7.3.3 (AREs only; in EREs and BREs, this matches `c`)
`{`	when followed by a character other than a digit, matches the left-brace character `{`; when followed by a digit, it is the beginning of a `bound` (see below)
`x`	where `x` is a single character with no other significance, matches that character

An RE cannot end with a backslash (`\`).

Note: If you have standard_conforming_strings turned off, any backslashes you write in literal string constants will need to be doubled. See Section 4.1.2.1 for more information.

Table 9-14. Regular Expression Quantifiers

Quantifier	Matches
`*`	a sequence of 0 or more matches of the atom
`+`	a sequence of 1 or more matches of the atom
`?`	a sequence of 0 or 1 matches of the atom
`{`*m*`}`	a sequence of exactly *m* matches of the atom
`{`*m*`,}`	a sequence of *m* or more matches of the atom
`{`*m*`,`*n*`}`	a sequence of *m* through *n* (inclusive) matches of the atom; *m* cannot exceed *n*
`*?`	non-greedy version of `*`
`+?`	non-greedy version of `+`
`??`	non-greedy version of `?`
`{`*m*`}?`	non-greedy version of `{`*m*`}`
`{`*m*`,}?`	non-greedy version of `{`*m*`,}`
`{`*m*`,`*n*`}?`	non-greedy version of `{`*m*`,`*n*`}`

The forms using `{...}` are known as *bounds*. The numbers *m* and *n* within a bound are unsigned decimal integers with permissible values from 0 to 255 inclusive.

Non-greedy quantifiers (available in AREs only) match the same possibilities as their corresponding normal (*greedy*) counterparts, but prefer the smallest number rather than the largest number of matches. See Section 9.7.3.5 for more detail.

> **Note:** A quantifier cannot immediately follow another quantifier, e.g., `**` is invalid. A quantifier cannot begin an expression or subexpression or follow `^` or `|`.

Table 9-15. Regular Expression Constraints

Constraint	Description
`^`	matches at the beginning of the string
`$`	matches at the end of the string
`(?=`*re*`)`	*positive lookahead* matches at any point where a substring matching *re* begins (AREs only)
`(?!`*re*`)`	*negative lookahead* matches at any point where no substring matching *re* begins (AREs only)

Lookahead constraints cannot contain *back references* (see Section 9.7.3.3), and all parentheses within them are considered non-capturing.

9.7.3.2. Bracket Expressions

A *bracket expression* is a list of characters enclosed in `[]`. It normally matches any single character from the list (but see below). If the list begins with `^`, it matches any single character *not* from the rest of the list. If two characters in the list are separated by `-`, this is shorthand for the full range

of characters between those two (inclusive) in the collating sequence, e.g., [0-9] in ASCII matches any decimal digit. It is illegal for two ranges to share an endpoint, e.g., a-c-e. Ranges are very collating-sequence-dependent, so portable programs should avoid relying on them.

To include a literal] in the list, make it the first character (after ^, if that is used). To include a literal -, make it the first or last character, or the second endpoint of a range. To use a literal - as the first endpoint of a range, enclose it in [. and .] to make it a collating element (see below). With the exception of these characters, some combinations using [(see next paragraphs), and escapes (AREs only), all other special characters lose their special significance within a bracket expression. In particular, \ is not special when following ERE or BRE rules, though it is special (as introducing an escape) in AREs.

Within a bracket expression, a collating element (a character, a multiple-character sequence that collates as if it were a single character, or a collating-sequence name for either) enclosed in [. and .] stands for the sequence of characters of that collating element. The sequence is treated as a single element of the bracket expression's list. This allows a bracket expression containing a multiple-character collating element to match more than one character, e.g., if the collating sequence includes a ch collating element, then the RE [[.ch.]]*c matches the first five characters of chchcc.

> **Note:** PostgreSQL currently does not support multi-character collating elements. This information describes possible future behavior.

Within a bracket expression, a collating element enclosed in [= and =] is an *equivalence class*, standing for the sequences of characters of all collating elements equivalent to that one, including itself. (If there are no other equivalent collating elements, the treatment is as if the enclosing delimiters were [. and .].) For example, if o and ^ are the members of an equivalence class, then [[=o=]], [[=^=]], and [o^] are all synonymous. An equivalence class cannot be an endpoint of a range.

Within a bracket expression, the name of a character class enclosed in [: and :] stands for the list of all characters belonging to that class. Standard character class names are: alnum, alpha, blank, cntrl, digit, graph, lower, print, punct, space, upper, xdigit. These stand for the character classes defined in ctype. A locale can provide others. A character class cannot be used as an endpoint of a range.

There are two special cases of bracket expressions: the bracket expressions [[:<:]] and [[:>:]] are constraints, matching empty strings at the beginning and end of a word respectively. A word is defined as a sequence of word characters that is neither preceded nor followed by word characters. A word character is an alnum character (as defined by ctype) or an underscore. This is an extension, compatible with but not specified by POSIX 1003.2, and should be used with caution in software intended to be portable to other systems. The constraint escapes described below are usually preferable; they are no more standard, but are easier to type.

9.7.3.3. Regular Expression Escapes

Escapes are special sequences beginning with \ followed by an alphanumeric character. Escapes come in several varieties: character entry, class shorthands, constraint escapes, and back references. A \ followed by an alphanumeric character but not constituting a valid escape is illegal in AREs. In EREs, there are no escapes: outside a bracket expression, a \ followed by an alphanumeric character merely stands for that character as an ordinary character, and inside a bracket expression, \ is an ordinary character. (The latter is the one actual incompatibility between EREs and AREs.)

Character-entry escapes exist to make it easier to specify non-printing and other inconvenient characters in REs. They are shown in Table 9-16.

Class-shorthand escapes provide shorthands for certain commonly-used character classes. They are shown in Table 9-17.

A *constraint escape* is a constraint, matching the empty string if specific conditions are met, written as an escape. They are shown in Table 9-18.

A *back reference* (`\n`) matches the same string matched by the previous parenthesized subexpression specified by the number *n* (see Table 9-19). For example, `([bc])\1` matches `bb` or `cc` but not `bc` or `cb`. The subexpression must entirely precede the back reference in the RE. Subexpressions are numbered in the order of their leading parentheses. Non-capturing parentheses do not define subexpressions.

> **Note:** Keep in mind that an escape's leading `\` will need to be doubled when entering the pattern as an SQL string constant. For example:
>
> `'123' ~ E'^\\d{3}'` *true*

Table 9-16. Regular Expression Character-entry Escapes

Escape	Description
`\a`	alert (bell) character, as in C
`\b`	backspace, as in C
`\B`	synonym for backslash (`\`) to help reduce the need for backslash doubling
`\c`*X*	(where *X* is any character) the character whose low-order 5 bits are the same as those of *X*, and whose other bits are all zero
`\e`	the character whose collating-sequence name is `ESC`, or failing that, the character with octal value 033
`\f`	form feed, as in C
`\n`	newline, as in C
`\r`	carriage return, as in C
`\t`	horizontal tab, as in C
`\u`*wxyz*	(where *wxyz* is exactly four hexadecimal digits) the UTF16 (Unicode, 16-bit) character `U+`*wxyz* in the local byte ordering
`\U`*stuvwxyz*	(where *stuvwxyz* is exactly eight hexadecimal digits) reserved for a hypothetical Unicode extension to 32 bits
`\v`	vertical tab, as in C
`\x`*hhh*	(where *hhh* is any sequence of hexadecimal digits) the character whose hexadecimal value is `0x`*hhh* (a single character no matter how many hexadecimal digits are used)
`\0`	the character whose value is `0` (the null byte)

Escape	Description
`\xy`	(where *xy* is exactly two octal digits, and is not a *back reference*) the character whose octal value is `0xy`
`\xyz`	(where *xyz* is exactly three octal digits, and is not a *back reference*) the character whose octal value is `0xyz`

Hexadecimal digits are `0-9`, `a-f`, and `A-F`. Octal digits are `0-7`.

The character-entry escapes are always taken as ordinary characters. For example, `\135` is `]` in ASCII, but `\135` does not terminate a bracket expression.

Table 9-17. Regular Expression Class-shorthand Escapes

Escape	Description
`\d`	`[[:digit:]]`
`\s`	`[[:space:]]`
`\w`	`[[:alnum:]_]` (note underscore is included)
`\D`	`[^[:digit:]]`
`\S`	`[^[:space:]]`
`\W`	`[^[:alnum:]_]` (note underscore is included)

Within bracket expressions, `\d`, `\s`, and `\w` lose their outer brackets, and `\D`, `\S`, and `\W` are illegal. (So, for example, `[a-c\d]` is equivalent to `[a-c[:digit:]]`. Also, `[a-c\D]`, which is equivalent to `[a-c^[:digit:]]`, is illegal.)

Table 9-18. Regular Expression Constraint Escapes

Escape	Description
`\A`	matches only at the beginning of the string (see Section 9.7.3.5 for how this differs from `^`)
`\m`	matches only at the beginning of a word
`\M`	matches only at the end of a word
`\y`	matches only at the beginning or end of a word
`\Y`	matches only at a point that is not the beginning or end of a word
`\Z`	matches only at the end of the string (see Section 9.7.3.5 for how this differs from `$`)

A word is defined as in the specification of `[[:<:]]` and `[[:>:]]` above. Constraint escapes are illegal within bracket expressions.

Table 9-19. Regular Expression Back References

Escape	Description
`\m`	(where *m* is a nonzero digit) a back reference to the *m*'th subexpression

Escape	Description
mnn	(where *m* is a nonzero digit, and *nn* is some more digits, and the decimal value *mnn* is not greater than the number of closing capturing parentheses seen so far) a back reference to the *mnn*'th subexpression

Note: There is an inherent ambiguity between octal character-entry escapes and back references, which is resolved by the following heuristics, as hinted at above. A leading zero always indicates an octal escape. A single non-zero digit, not followed by another digit, is always taken as a back reference. A multi-digit sequence not starting with a zero is taken as a back reference if it comes after a suitable subexpression (i.e., the number is in the legal range for a back reference), and otherwise is taken as octal.

9.7.3.4. Regular Expression Metasyntax

In addition to the main syntax described above, there are some special forms and miscellaneous syntactic facilities available.

An RE can begin with one of two special *director* prefixes. If an RE begins with ***:, the rest of the RE is taken as an ARE. (This normally has no effect in PostgreSQL, since REs are assumed to be AREs; but it does have an effect if ERE or BRE mode had been specified by the *flags* parameter to a regex function.) If an RE begins with ***=, the rest of the RE is taken to be a literal string, with all characters considered ordinary characters.

An ARE can begin with *embedded options*: a sequence (?*xyz*) (where *xyz* is one or more alphabetic characters) specifies options affecting the rest of the RE. These options override any previously determined options — in particular, they can override the case-sensitivity behavior implied by a regex operator, or the *flags* parameter to a regex function. The available option letters are shown in Table 9-20. Note that these same option letters are used in the *flags* parameters of regex functions.

Table 9-20. ARE Embedded-option Letters

Option	Description
b	rest of RE is a BRE
c	case-sensitive matching (overrides operator type)
e	rest of RE is an ERE
i	case-insensitive matching (see Section 9.7.3.5) (overrides operator type)
m	historical synonym for n
n	newline-sensitive matching (see Section 9.7.3.5)
p	partial newline-sensitive matching (see Section 9.7.3.5)
q	rest of RE is a literal ("quoted") string, all ordinary characters
s	non-newline-sensitive matching (default)

Option	Description
t	tight syntax (default; see below)
w	inverse partial newline-sensitive ("weird") matching (see Section 9.7.3.5)
x	expanded syntax (see below)

Embedded options take effect at the) terminating the sequence. They can appear only at the start of an ARE (after the ***: director if any).

In addition to the usual (*tight*) RE syntax, in which all characters are significant, there is an *expanded* syntax, available by specifying the embedded x option. In the expanded syntax, white-space characters in the RE are ignored, as are all characters between a # and the following newline (or the end of the RE). This permits paragraphing and commenting a complex RE. There are three exceptions to that basic rule:

- a white-space character or # preceded by \ is retained
- white space or # within a bracket expression is retained
- white space and comments cannot appear within multi-character symbols, such as (?:

For this purpose, white-space characters are blank, tab, newline, and any character that belongs to the *space* character class.

Finally, in an ARE, outside bracket expressions, the sequence (?#*ttt*) (where *ttt* is any text not containing a)) is a comment, completely ignored. Again, this is not allowed between the characters of multi-character symbols, like (?:. Such comments are more a historical artifact than a useful facility, and their use is deprecated; use the expanded syntax instead.

None of these metasyntax extensions is available if an initial ***= director has specified that the user's input be treated as a literal string rather than as an RE.

9.7.3.5. Regular Expression Matching Rules

In the event that an RE could match more than one substring of a given string, the RE matches the one starting earliest in the string. If the RE could match more than one substring starting at that point, either the longest possible match or the shortest possible match will be taken, depending on whether the RE is *greedy* or *non-greedy*.

Whether an RE is greedy or not is determined by the following rules:

- Most atoms, and all constraints, have no greediness attribute (because they cannot match variable amounts of text anyway).
- Adding parentheses around an RE does not change its greediness.
- A quantified atom with a fixed-repetition quantifier ({*m*} or {*m*}?) has the same greediness (possibly none) as the atom itself.
- A quantified atom with other normal quantifiers (including {*m*,*n*} with *m* equal to *n*) is greedy (prefers longest match).
- A quantified atom with a non-greedy quantifier (including {*m*,*n*}? with *m* equal to *n*) is non-greedy (prefers shortest match).
- A branch — that is, an RE that has no top-level | operator — has the same greediness as the first quantified atom in it that has a greediness attribute.

- An RE consisting of two or more branches connected by the | operator is always greedy.

The above rules associate greediness attributes not only with individual quantified atoms, but with branches and entire REs that contain quantified atoms. What that means is that the matching is done in such a way that the branch, or whole RE, matches the longest or shortest possible substring *as a whole*. Once the length of the entire match is determined, the part of it that matches any particular subexpression is determined on the basis of the greediness attribute of that subexpression, with subexpressions starting earlier in the RE taking priority over ones starting later.

An example of what this means:

```
SELECT SUBSTRING('XY1234Z', 'Y*([0-9]{1,3})');
Result: 123
SELECT SUBSTRING('XY1234Z', 'Y*?([0-9]{1,3})');
Result: 1
```

In the first case, the RE as a whole is greedy because `Y*` is greedy. It can match beginning at the `Y`, and it matches the longest possible string starting there, i.e., `Y123`. The output is the parenthesized part of that, or `123`. In the second case, the RE as a whole is non-greedy because `Y*?` is non-greedy. It can match beginning at the `Y`, and it matches the shortest possible string starting there, i.e., `Y1`. The subexpression `[0-9]{1,3}` is greedy but it cannot change the decision as to the overall match length; so it is forced to match just `1`.

In short, when an RE contains both greedy and non-greedy subexpressions, the total match length is either as long as possible or as short as possible, according to the attribute assigned to the whole RE. The attributes assigned to the subexpressions only affect how much of that match they are allowed to "eat" relative to each other.

The quantifiers `{1,1}` and `{1,1}?` can be used to force greediness or non-greediness, respectively, on a subexpression or a whole RE.

Match lengths are measured in characters, not collating elements. An empty string is considered longer than no match at all. For example: `bb*` matches the three middle characters of `abbbc`; `(week|wee)(night|knights)` matches all ten characters of `weeknights`; when `(.*).*` is matched against `abc` the parenthesized subexpression matches all three characters; and when `(a*)*` is matched against `bc` both the whole RE and the parenthesized subexpression match an empty string.

If case-independent matching is specified, the effect is much as if all case distinctions had vanished from the alphabet. When an alphabetic that exists in multiple cases appears as an ordinary character outside a bracket expression, it is effectively transformed into a bracket expression containing both cases, e.g., `x` becomes `[xX]`. When it appears inside a bracket expression, all case counterparts of it are added to the bracket expression, e.g., `[x]` becomes `[xX]` and `[^x]` becomes `[^xX]`.

If newline-sensitive matching is specified, `.` and bracket expressions using `^` will never match the newline character (so that matches will never cross newlines unless the RE explicitly arranges it) and `^` and `$` will match the empty string after and before a newline respectively, in addition to matching at beginning and end of string respectively. But the ARE escapes `\A` and `\Z` continue to match beginning or end of string *only*.

If partial newline-sensitive matching is specified, this affects `.` and bracket expressions as with newline-sensitive matching, but not `^` and `$`.

If inverse partial newline-sensitive matching is specified, this affects `^` and `$` as with newline-sensitive matching, but not `.` and bracket expressions. This isn't very useful but is provided for symmetry.

9.7.3.6. Limits and Compatibility

No particular limit is imposed on the length of REs in this implementation. However, programs intended to be highly portable should not employ REs longer than 256 bytes, as a POSIX-compliant implementation can refuse to accept such REs.

The only feature of AREs that is actually incompatible with POSIX EREs is that `\` does not lose its special significance inside bracket expressions. All other ARE features use syntax which is illegal or has undefined or unspecified effects in POSIX EREs; the `***` syntax of directors likewise is outside the POSIX syntax for both BREs and EREs.

Many of the ARE extensions are borrowed from Perl, but some have been changed to clean them up, and a few Perl extensions are not present. Incompatibilities of note include `\b`, `\B`, the lack of special treatment for a trailing newline, the addition of complemented bracket expressions to the things affected by newline-sensitive matching, the restrictions on parentheses and back references in lookahead constraints, and the longest/shortest-match (rather than first-match) matching semantics.

Two significant incompatibilities exist between AREs and the ERE syntax recognized by pre-7.4 releases of PostgreSQL:

- In AREs, `\` followed by an alphanumeric character is either an escape or an error, while in previous releases, it was just another way of writing the alphanumeric. This should not be much of a problem because there was no reason to write such a sequence in earlier releases.
- In AREs, `\` remains a special character within `[]`, so a literal `\` within a bracket expression must be written `\\`.

9.7.3.7. Basic Regular Expressions

BREs differ from EREs in several respects. In BREs, `|`, `+`, and `?` are ordinary characters and there is no equivalent for their functionality. The delimiters for bounds are `\{` and `\}`, with `{` and `}` by themselves ordinary characters. The parentheses for nested subexpressions are `\(` and `\)`, with `(` and `)` by themselves ordinary characters. `^` is an ordinary character except at the beginning of the RE or the beginning of a parenthesized subexpression, `$` is an ordinary character except at the end of the RE or the end of a parenthesized subexpression, and `*` is an ordinary character if it appears at the beginning of the RE or the beginning of a parenthesized subexpression (after a possible leading `^`). Finally, single-digit back references are available, and `\<` and `\>` are synonyms for `[[:<:]]` and `[[:>:]]` respectively; no other escapes are available in BREs.

9.8. Data Type Formatting Functions

The PostgreSQL formatting functions provide a powerful set of tools for converting various data types (date/time, integer, floating point, numeric) to formatted strings and for converting from formatted strings to specific data types. Table 9-21 lists them. These functions all follow a common calling convention: the first argument is the value to be formatted and the second argument is a template that defines the output or input format.

A single-argument `to_timestamp` function is also available; it accepts a `double precision` argument and converts from Unix epoch (seconds since 1970-01-01 00:00:00+00) to `timestamp with time zone`. (`Integer` Unix epochs are implicitly cast to `double precision`.)

Table 9-21. Formatting Functions

Function	Return Type	Description	Example
to_char(timestamp, text)	text	convert time stamp to string	to_char(current_timestamp, 'HH12:MI:SS')
to_char(interval, text)	text	convert interval to string	to_char(interval '15h 2m 12s', 'HH24:MI:SS')
to_char(int, text)	text	convert integer to string	to_char(125, '999')
to_char(double precision, text)	text	convert real/double precision to string	to_char(125.8::real, '999D9')
to_char(numeric, text)	text	convert numeric to string	to_char(-125.8, '999D99S')
to_date(text, text)	date	convert string to date	to_date('05 Dec 2000', 'DD Mon YYYY')
to_number(text, text)	numeric	convert string to numeric	to_number('12,454.8-', '99G999D9S')
to_timestamp(text, text)	timestamp with time zone	convert string to time stamp	to_timestamp('05 Dec 2000', 'DD Mon YYYY')
to_timestamp(double precision)	timestamp with time zone	convert Unix epoch to time stamp	to_timestamp(1284352323)

In a to_char output template string, there are certain patterns that are recognized and replaced with appropriately-formatted data based on the given value. Any text that is not a template pattern is simply copied verbatim. Similarly, in an input template string (for the other functions), template patterns identify the values to be supplied by the input data string.

Table 9-22 shows the template patterns available for formatting date and time values.

Table 9-22. Template Patterns for Date/Time Formatting

Pattern	Description
HH	hour of day (01-12)
HH12	hour of day (01-12)
HH24	hour of day (00-23)
MI	minute (00-59)
SS	second (00-59)
MS	millisecond (000-999)
US	microsecond (000000-999999)
SSSS	seconds past midnight (0-86399)
AM, am, PM or pm	meridiem indicator (without periods)
A.M., a.m., P.M. or p.m.	meridiem indicator (with periods)
Y,YYY	year (4 or more digits) with comma
YYYY	year (4 or more digits)
YYY	last 3 digits of year
YY	last 2 digits of year

Pattern	Description
Y	last digit of year
IYYY	ISO 8601 week-numbering year (4 or more digits)
IYY	last 3 digits of ISO 8601 week-numbering year
IY	last 2 digits of ISO 8601 week-numbering year
I	last digit of ISO 8601 week-numbering year
BC, bc, AD or ad	era indicator (without periods)
B.C., b.c., A.D. or a.d.	era indicator (with periods)
MONTH	full upper case month name (blank-padded to 9 chars)
Month	full capitalized month name (blank-padded to 9 chars)
month	full lower case month name (blank-padded to 9 chars)
MON	abbreviated upper case month name (3 chars in English, localized lengths vary)
Mon	abbreviated capitalized month name (3 chars in English, localized lengths vary)
mon	abbreviated lower case month name (3 chars in English, localized lengths vary)
MM	month number (01-12)
DAY	full upper case day name (blank-padded to 9 chars)
Day	full capitalized day name (blank-padded to 9 chars)
day	full lower case day name (blank-padded to 9 chars)
DY	abbreviated upper case day name (3 chars in English, localized lengths vary)
Dy	abbreviated capitalized day name (3 chars in English, localized lengths vary)
dy	abbreviated lower case day name (3 chars in English, localized lengths vary)
DDD	day of year (001-366)
IDDD	day of ISO 8601 week-numbering year (001-371; day 1 of the year is Monday of the first ISO week)
DD	day of month (01-31)
D	day of the week, Sunday (1) to Saturday (7)
ID	ISO 8601 day of the week, Monday (1) to Sunday (7)
W	week of month (1-5) (the first week starts on the first day of the month)
WW	week number of year (1-53) (the first week starts on the first day of the year)

Pattern	Description
IW	week number of ISO 8601 week-numbering year (01-53; the first Thursday of the year is in week 1)
CC	century (2 digits) (the twenty-first century starts on 2001-01-01)
J	Julian Day (integer days since November 24, 4714 BC at midnight UTC)
Q	quarter (ignored by to_date and to_timestamp)
RM	month in upper case Roman numerals (I-XII; I=January)
rm	month in lower case Roman numerals (i-xii; i=January)
TZ	upper case time-zone name
tz	lower case time-zone name
OF	time-zone offset

Modifiers can be applied to any template pattern to alter its behavior. For example, FMMonth is the Month pattern with the FM modifier. Table 9-23 shows the modifier patterns for date/time formatting.

Table 9-23. Template Pattern Modifiers for Date/Time Formatting

Modifier	Description	Example
FM prefix	fill mode (suppress padding blanks and trailing zeroes)	FMMonth
TH suffix	upper case ordinal number suffix	DDTH, e.g., 12TH
th suffix	lower case ordinal number suffix	DDth, e.g., 12th
FX prefix	fixed format global option (see usage notes)	FX Month DD Day
TM prefix	translation mode (print localized day and month names based on lc_time)	TMMonth
SP suffix	spell mode (not implemented)	DDSP

Usage notes for date/time formatting:

- FM suppresses leading zeroes and trailing blanks that would otherwise be added to make the output of a pattern be fixed-width. In PostgreSQL, FM modifies only the next specification, while in Oracle FM affects all subsequent specifications, and repeated FM modifiers toggle fill mode on and off.
- TM does not include trailing blanks.
- to_timestamp and to_date skip multiple blank spaces in the input string unless the FX option is used. For example, to_timestamp('2000 JUN', 'YYYY MON') works, but to_timestamp('2000 JUN', 'FXYYYY MON') returns an error because to_timestamp expects one space only. FX must be specified as the first item in the template.

- to_timestamp and to_date exist to handle input formats that cannot be converted by simple casting. These functions interpret input liberally, with minimal error checking. While they produce valid output, the conversion can yield unexpected results. For example, input to these functions is not restricted by normal ranges, thus to_date('20096040','YYYYMMDD') returns 2014-01-17 rather than causing an error. Casting does not have this behavior.
- Ordinary text is allowed in to_char templates and will be output literally. You can put a substring in double quotes to force it to be interpreted as literal text even if it contains pattern key words. For example, in '"Hello Year "YYYY', the YYYY will be replaced by the year data, but the single Y in Year will not be. In to_date, to_number, and to_timestamp, double-quoted strings skip the number of input characters contained in the string, e.g. "XX" skips two input characters.
- If you want to have a double quote in the output you must precede it with a backslash, for example '\"YYYY Month\"'.
- If the year format specification is less than four digits, e.g. YYY, and the supplied year is less than four digits, the year will be adjusted to be nearest to the year 2020, e.g. 95 becomes 1995.
- The YYYY conversion from string to timestamp or date has a restriction when processing years with more than 4 digits. You must use some non-digit character or template after YYYY, otherwise the year is always interpreted as 4 digits. For example (with the year 20000): to_date('200001131', 'YYYYMMDD') will be interpreted as a 4-digit year; instead use a non-digit separator after the year, like to_date('20000-1131', 'YYYY-MMDD') or to_date('20000Nov31', 'YYYYMonDD').
- In conversions from string to timestamp or date, the CC (century) field is ignored if there is a YYY, YYYY or Y,YYY field. If CC is used with YY or Y then the year is computed as the year in the specified century. If the century is specified but the year is not, the first year of the century is assumed.
- An ISO 8601 week-numbering date (as distinct from a Gregorian date) can be specified to to_timestamp and to_date in one of two ways:
  - Year, week number, and weekday: for example to_date('2006-42-4', 'IYYY-IW-ID') returns the date 2006-10-19. If you omit the weekday it is assumed to be 1 (Monday).
  - Year and day of year: for example to_date('2006-291', 'IYYY-IDDD') also returns 2006-10-19.

  Attempting to enter a date using a mixture of ISO 8601 week-numbering fields and Gregorian date fields is nonsensical, and will cause an error. In the context of an ISO 8601 week-numbering year, the concept of a "month" or "day of month" has no meaning. In the context of a Gregorian year, the ISO week has no meaning.

  Caution

  While to_date will reject a mixture of Gregorian and ISO week-numbering date fields, to_char will not, since output format specifications like YYYY-MM-DD (IYYY-IDDD) can be useful. But avoid writing something like IYYY-MM-DD; that would yield surprising results near the start of the year. (See Section 9.9.1 for more information.)

- In a conversion from string to timestamp, millisecond (MS) or microsecond (US) values are used as the seconds digits after the decimal point. For example to_timestamp('12:3', 'SS:MS') is not 3 milliseconds, but 300, because the conversion counts it as 12 + 0.3 seconds. This means for the format SS:MS, the input values 12:3, 12:30, and 12:300 specify the same number of

milliseconds. To get three milliseconds, one must use `12:003`, which the conversion counts as 12 + 0.003 = 12.003 seconds.

Here is a more complex example: `to_timestamp('15:12:02.020.001230', 'HH:MI:SS.MS.US')` is 15 hours, 12 minutes, and 2 seconds + 20 milliseconds + 1230 microseconds = 2.021230 seconds.

- `to_char(..., 'ID')`'s day of the week numbering matches the `extract(isodow from ...)` function, but `to_char(..., 'D')`'s does not match `extract(dow from ...)`'s day numbering.
- `to_char(interval)` formats `HH` and `HH12` as shown on a 12-hour clock, i.e. zero hours and 36 hours output as `12`, while `HH24` outputs the full hour value, which can exceed 23 for intervals.

Table 9-24 shows the template patterns available for formatting numeric values.

Table 9-24. Template Patterns for Numeric Formatting

Pattern	Description
`9`	value with the specified number of digits
`0`	value with leading zeros
`.` (period)	decimal point
`,` (comma)	group (thousand) separator
`PR`	negative value in angle brackets
`S`	sign anchored to number (uses locale)
`L`	currency symbol (uses locale)
`D`	decimal point (uses locale)
`G`	group separator (uses locale)
`MI`	minus sign in specified position (if number $<$ 0)
`PL`	plus sign in specified position (if number $>$ 0)
`SG`	plus/minus sign in specified position
`RN`	Roman numeral (input between 1 and 3999)
`TH` or `th`	ordinal number suffix
`V`	shift specified number of digits (see notes)
`EEEE`	exponent for scientific notation

Usage notes for numeric formatting:

- A sign formatted using `SG`, `PL`, or `MI` is not anchored to the number; for example, `to_char(-12, 'MI9999')` produces `'- 12'` but `to_char(-12, 'S9999')` produces `' -12'`. The Oracle implementation does not allow the use of `MI` before `9`, but rather requires that `9` precede `MI`.
- `9` results in a value with the same number of digits as there are `9`s. If a digit is not available it outputs a space.
- `TH` does not convert values less than zero and does not convert fractional numbers.
- `PL`, `SG`, and `TH` are PostgreSQL extensions.
- `V` effectively multiplies the input values by `10^n`, where *n* is the number of digits following `V`. `to_char` does not support the use of `V` combined with a decimal point (e.g., `99.9V99` is not

allowed).

- `EEEE` (scientific notation) cannot be used in combination with any of the other formatting patterns or modifiers other than digit and decimal point patterns, and must be at the end of the format string (e.g., `9.99EEEE` is a valid pattern).

Certain modifiers can be applied to any template pattern to alter its behavior. For example, `FM9999` is the `9999` pattern with the `FM` modifier. Table 9-25 shows the modifier patterns for numeric formatting.

Table 9-25. Template Pattern Modifiers for Numeric Formatting

Modifier	Description	Example
`FM` prefix	fill mode (suppress padding blanks and trailing zeroes)	`FM9999`
`TH` suffix	upper case ordinal number suffix	`999TH`
`th` suffix	lower case ordinal number suffix	`999th`

Table 9-26 shows some examples of the use of the `to_char` function.

Table 9-26. `to_char` Examples

Expression	Result
`to_char(current_timestamp, 'Day, DD  HH12:MI:SS')`	`'Tuesday  , 06  05:39:18'`
`to_char(current_timestamp, 'FMDay, FMDD  HH12:MI:SS')`	`'Tuesday, 6  05:39:18'`
`to_char(-0.1, '99.99')`	`'  -.10'`
`to_char(-0.1, 'FM9.99')`	`'-.1'`
`to_char(0.1, '0.9')`	`' 0.1'`
`to_char(12, '9990999.9')`	`'    0012.0'`
`to_char(12, 'FM9990999.9')`	`'0012.'`
`to_char(485, '999')`	`' 485'`
`to_char(-485, '999')`	`'-485'`
`to_char(485, '9 9 9')`	`' 4 8 5'`
`to_char(1485, '9,999')`	`' 1,485'`
`to_char(1485, '9G999')`	`' 1 485'`
`to_char(148.5, '999.999')`	`' 148.500'`
`to_char(148.5, 'FM999.999')`	`'148.5'`
`to_char(148.5, 'FM999.990')`	`'148.500'`
`to_char(148.5, '999D999')`	`' 148,500'`
`to_char(3148.5, '9G999D999')`	`' 3 148,500'`
`to_char(-485, '999S')`	`'485-'`
`to_char(-485, '999MI')`	`'485-'`
`to_char(485, '999MI')`	`'485 '`

Expression	Result
to_char(485, 'FM999MI')	'485'
to_char(485, 'PL999')	'+485'
to_char(485, 'SG999')	'+485'
to_char(-485, 'SG999')	'-485'
to_char(-485, '9SG99')	'4-85'
to_char(-485, '999PR')	'<485>'
to_char(485, 'L999')	'DM 485
to_char(485, 'RN')	' CDLXXXV'
to_char(485, 'FMRN')	'CDLXXXV'
to_char(5.2, 'FMRN')	'V'
to_char(482, '999th')	' 482nd'
to_char(485, '"Good number:"999')	'Good number: 485'
to_char(485.8, '"Pre:"999" Post:" .999')	'Pre: 485 Post: .800'
to_char(12, '99V999')	' 12000'
to_char(12.4, '99V999')	' 12400'
to_char(12.45, '99V9')	' 125'
to_char(0.0004859, '9.99EEEE')	' 4.86e-04'

9.9. Date/Time Functions and Operators

Table 9-28 shows the available functions for date/time value processing, with details appearing in the following subsections. Table 9-27 illustrates the behaviors of the basic arithmetic operators (+, *, etc.). For formatting functions, refer to Section 9.8. You should be familiar with the background information on date/time data types from Section 8.5.

All the functions and operators described below that take time or timestamp inputs actually come in two variants: one that takes time with time zone or timestamp with time zone, and one that takes time without time zone or timestamp without time zone. For brevity, these variants are not shown separately. Also, the + and * operators come in commutative pairs (for example both date + integer and integer + date); we show only one of each such pair.

Table 9-27. Date/Time Operators

Operator	Example	Result
+	date '2001-09-28' + integer '7'	date '2001-10-05'
+	date '2001-09-28' + interval '1 hour'	timestamp '2001-09-28 01:00:00'
+	date '2001-09-28' + time '03:00'	timestamp '2001-09-28 03:00:00'
+	interval '1 day' + interval '1 hour'	interval '1 day 01:00:00'

Operator	Example	Result
+	timestamp '2001-09-28 01:00' + interval '23 hours'	timestamp '2001-09-29 00:00:00'
+	time '01:00' + interval '3 hours'	time '04:00:00'
-	- interval '23 hours'	interval '-23:00:00'
-	date '2001-10-01' - date '2001-09-28'	integer '3' (days)
-	date '2001-10-01' - integer '7'	date '2001-09-24'
-	date '2001-09-28' - interval '1 hour'	timestamp '2001-09-27 23:00:00'
-	time '05:00' - time '03:00'	interval '02:00:00'
-	time '05:00' - interval '2 hours'	time '03:00:00'
-	timestamp '2001-09-28 23:00' - interval '23 hours'	timestamp '2001-09-28 00:00:00'
-	interval '1 day' - interval '1 hour'	interval '1 day -01:00:00'
-	timestamp '2001-09-29 03:00' - timestamp '2001-09-27 12:00'	interval '1 day 15:00:00'
*	900 * interval '1 second'	interval '00:15:00'
*	21 * interval '1 day'	interval '21 days'
*	double precision '3.5' * interval '1 hour'	interval '03:30:00'
/	interval '1 hour' / double precision '1.5'	interval '00:40:00'

Table 9-28. Date/Time Functions

Function	Return Type	Description	Example	Result
age(timestamp, timestamp)	interval	Subtract arguments, producing a "symbolic" result that uses years and months, rather than just days	age(timestamp '2001-04-10', timestamp '1957-06-13')	43 years 9 mons 27 days
age(timestamp)	interval	Subtract from current_date (at midnight)	age(timestamp '1957-06-13')	43 years 8 mons 3 days

Function	Return Type	Description	Example	Result
clock_timestamp()	timestamp with time zone	Current date and time (changes during statement execution); see Section 9.9.4		
current_date	date	Current date; see Section 9.9.4		
current_time	time with time zone	Current time of day; see Section 9.9.4		
current_timestamp	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		
date_part(text, timestamp)	double precision	Get subfield (equivalent to extract); see Section 9.9.1	date_part('hour', timestamp '2001-02-16 20:38:40')	20
date_part(text, interval)	double precision	Get subfield (equivalent to extract); see Section 9.9.1	date_part('month', interval '2 years 3 months')	3
date_trunc(text, timestamp)	timestamp	Truncate to specified precision; see also Section 9.9.2	date_trunc('hour', timestamp '2001-02-16 20:38:40')	2001-02-16 20:00:00
date_trunc(text, interval)	interval	Truncate to specified precision; see also Section 9.9.2	date_trunc('hour', interval '2 days 3 hours 40 minutes')	2 days 03:00:00
extract(field from timestamp)	double precision	Get subfield; see Section 9.9.1	extract(hour from timestamp '2001-02-16 20:38:40')	20
extract(field from interval)	double precision	Get subfield; see Section 9.9.1	extract(month from interval '2 years 3 months')	3
isfinite(date)	boolean	Test for finite date (not +/-infinity)	isfinite(date '2001-02-16')	true
isfinite(timestamp)	boolean	Test for finite time stamp (not +/-infinity)	isfinite(timestamp '2001-02-16 21:28:30')	true
isfinite(interval)	boolean	Test for finite interval	isfinite(interval '4 hours')	true

Function	Return Type	Description	Example	Result
justify_days(interval)	interval	Adjust interval so 30-day time periods are represented as months	justify_days(interval '35 days')	1 mon 5 days
justify_hours(interval)	interval	Adjust interval so 24-hour time periods are represented as days	justify_hours(interval '27 hours')	1 day 03:00:00
justify_interval(interval)	interval	Adjust interval using justify_days and justify_hours, with additional sign adjustments	justify_interval(interval '1 mon -1 hour')	29 days 23:00:00
localtime	time	Current time of day; see Section 9.9.4		
localtimestamp	timestamp	Current date and time (start of current transaction); see Section 9.9.4		
make_date(year int, month int, day int)	date	Create date from year, month and day fields	make_date(2013, 7, 15)	2013-07-15
make_interval(years int DEFAULT 0, months int DEFAULT 0, weeks int DEFAULT 0, days int DEFAULT 0, hours int DEFAULT 0, mins int DEFAULT 0, secs double precision DEFAULT 0.0)	interval	Create interval from years, months, weeks, days, hours, minutes and seconds fields	make_interval(days := 10)	10 days
make_time(hour int, min int, sec double precision)	time	Create time from hour, minute and seconds fields	make_time(8, 15, 23.5)	08:15:23.5

Function	Return Type	Description	Example	Result
make_timestamp(year int, month int, day int, hour int, min int, sec double precision)	timestamp	Create timestamp from year, month, day, hour, minute and seconds fields	make_timestamp(2013, 7, 15, 8, 15, 23.5)	2013-07-15 08:15:23.5
make_timestamptz(year int, month int, day int, hour int, min int, sec double precision, [timezone text])	timestamp with time zone	Create timestamp with time zone from year, month, day, hour, minute and seconds fields. When timezone is not specified, then current time zone is used.	make_timestamptz(2013, 7, 15, 8, 15, 23.5)	2013-07-15 08:15:23.5+01
now()	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		
statement_timestamp()	timestamp with time zone	Current date and time (start of current statement); see Section 9.9.4		
timeofday()	text	Current date and time (like clock_timestamp, but as a text string); see Section 9.9.4		
transaction_timestamp()	timestamp with time zone	Current date and time (start of current transaction); see Section 9.9.4		

In addition to these functions, the SQL OVERLAPS operator is supported:

```
(start1, end1) OVERLAPS (start2, end2)
(start1, length1) OVERLAPS (start2, length2)
```

This expression yields true when two time periods (defined by their endpoints) overlap, false when they do not overlap. The endpoints can be specified as pairs of dates, times, or time stamps; or as a date, time, or time stamp followed by an interval. When a pair of values is provided, either the start or the end can be written first; OVERLAPS automatically takes the earlier value of the pair as the start. Each time period is considered to represent the half-open interval *start* <= *time* < *end*, unless *start* and *end* are equal in which case it represents that single time instant. This means for instance

that two time periods with only an endpoint in common do not overlap.

```
SELECT (DATE '2001-02-16', DATE '2001-12-21') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: true
SELECT (DATE '2001-02-16', INTERVAL '100 days') OVERLAPS
       (DATE '2001-10-30', DATE '2002-10-30');
Result: false
SELECT (DATE '2001-10-29', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: false
SELECT (DATE '2001-10-30', DATE '2001-10-30') OVERLAPS
       (DATE '2001-10-30', DATE '2001-10-31');
Result: true
```

When adding an `interval` value to (or subtracting an `interval` value from) a `timestamp with time zone` value, the days component advances or decrements the date of the `timestamp with time zone` by the indicated number of days. Across daylight saving time changes (when the session time zone is set to a time zone that recognizes DST), this means `interval '1 day'` does not necessarily equal `interval '24 hours'`. For example, with the session time zone set to `CST7CDT`, `timestamp with time zone '2005-04-02 12:00-07' + interval '1 day'` will produce `timestamp with time zone '2005-04-03 12:00-06'`, while adding `interval '24 hours'` to the same initial `timestamp with time zone` produces `timestamp with time zone '2005-04-03 13:00-06'`, as there is a change in daylight saving time at `2005-04-03 02:00` in time zone `CST7CDT`.

Note there can be ambiguity in the `months` field returned by `age` because different months have different numbers of days. PostgreSQL's approach uses the month from the earlier of the two dates when calculating partial months. For example, `age('2004-06-01', '2004-04-30')` uses April to yield `1 mon 1 day`, while using May would yield `1 mon 2 days` because May has 31 days, while April has only 30.

Subtraction of dates and timestamps can also be complex. One conceptually simple way to perform subtraction is to convert each value to a number of seconds using `EXTRACT(EPOCH FROM ...)`, then subtract the results; this produces the number of *seconds* between the two values. This will adjust for the number of days in each month, timezone changes, and daylight saving time adjustments. Subtraction of date or timestamp values with the "-" operator returns the number of days (24-hours) and hours/minutes/seconds between the values, making the same adjustments. The `age` function returns years, months, days, and hours/minutes/seconds, performing field-by-field subtraction and then adjusting for negative field values. The following queries illustrate the differences in these approaches. The sample results were produced with `timezone = 'US/Eastern'`; there is a daylight saving time change between the two dates used:

```
SELECT EXTRACT(EPOCH FROM timestamptz '2013-07-01 12:00:00') -
       EXTRACT(EPOCH FROM timestamptz '2013-03-01 12:00:00');
Result: 10537200
SELECT (EXTRACT(EPOCH FROM timestamptz '2013-07-01 12:00:00') -
        EXTRACT(EPOCH FROM timestamptz '2013-03-01 12:00:00'))
        / 60 / 60 / 24;
Result: 121.958333333333
SELECT timestamptz '2013-07-01 12:00:00' - timestamptz '2013-03-01 12:00:00';
Result: 121 days 23:00:00
SELECT age(timestamptz '2013-07-01 12:00:00', timestamptz '2013-03-01 12:00:00');
Result: 4 mons
```

9.9.1. EXTRACT, date_part

```
EXTRACT(field FROM source)
```

The extract function retrieves subfields such as year or hour from date/time values. *source* must be a value expression of type timestamp, time, or interval. (Expressions of type date are cast to timestamp and can therefore be used as well.) *field* is an identifier or string that selects what field to extract from the source value. The extract function returns values of type double precision. The following are valid field names:

century

The century

```
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2000-12-16 12:21:13');
Result: 20
SELECT EXTRACT(CENTURY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 21
```

The first century starts at 0001-01-01 00:00:00 AD, although they did not know it at the time. This definition applies to all Gregorian calendar countries. There is no century number 0, you go from -1 century to 1 century. If you disagree with this, please write your complaint to: Pope, Cathedral Saint-Peter of Roma, Vatican.

day

For timestamp values, the day (of the month) field (1 - 31) ; for interval values, the number of days

```
SELECT EXTRACT(DAY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 16

SELECT EXTRACT(DAY FROM INTERVAL '40 days 1 minute');
Result: 40
```

decade

The year field divided by 10

```
SELECT EXTRACT(DECADE FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 200
```

dow

The day of the week as Sunday (0) to Saturday (6)

```
SELECT EXTRACT(DOW FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 5
```

Note that extract's day of the week numbering differs from that of the to_char(..., 'D') function.

doy

The day of the year (1 - 365/366)

```
SELECT EXTRACT(DOY FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 47
```

epoch

For timestamp with time zone values, the number of seconds since 1970-01-01 00:00:00 UTC (can be negative); for date and timestamp values, the number of seconds since 1970-01-01 00:00:00 local time; for interval values, the total number of seconds in the interval

```
SELECT EXTRACT(EPOCH FROM TIMESTAMP WITH TIME ZONE '2001-02-16 20:38:40.12-08');
Result: 982384720.12

SELECT EXTRACT(EPOCH FROM INTERVAL '5 days 3 hours');
Result: 442800
```

Here is how you can convert an epoch value back to a time stamp:

```
SELECT TIMESTAMP WITH TIME ZONE 'epoch' + 982384720.12 * INTERVAL '1 second';
```

(The `to_timestamp` function encapsulates the above conversion.)

`hour`

The hour field (0 - 23)

```
SELECT EXTRACT(HOUR FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 20
```

`isodow`

The day of the week as Monday (`1`) to Sunday (`7`)

```
SELECT EXTRACT(ISODOW FROM TIMESTAMP '2001-02-18 20:38:40');
Result: 7
```

This is identical to `dow` except for Sunday. This matches the ISO 8601 day of the week numbering.

`isoyear`

The ISO 8601 week-numbering year that the date falls in (not applicable to intervals)

```
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-01');
Result: 2005
SELECT EXTRACT(ISOYEAR FROM DATE '2006-01-02');
Result: 2006
```

Each ISO 8601 week-numbering year begins with the Monday of the week containing the 4th of January, so in early January or late December the ISO year may be different from the Gregorian year. See the `week` field for more information.

This field is not available in PostgreSQL releases prior to 8.3.

`microseconds`

The seconds field, including fractional parts, multiplied by 1 000 000; note that this includes full seconds

```
SELECT EXTRACT(MICROSECONDS FROM TIME '17:12:28.5');
Result: 28500000
```

`millennium`

The millennium

```
SELECT EXTRACT(MILLENNIUM FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 3
```

Years in the 1900s are in the second millennium. The third millennium started January 1, 2001.

`milliseconds`

The seconds field, including fractional parts, multiplied by 1000. Note that this includes full seconds.

```
SELECT EXTRACT(MILLISECONDS FROM TIME '17:12:28.5');
Result: 28500
```

`minute`

The minutes field (0 - 59)

```
SELECT EXTRACT(MINUTE FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 38
```

`month`

For `timestamp` values, the number of the month within the year (1 - 12) ; for `interval` values, the number of months, modulo 12 (0 - 11)

```
SELECT EXTRACT(MONTH FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 2

SELECT EXTRACT(MONTH FROM INTERVAL '2 years 3 months');
Result: 3

SELECT EXTRACT(MONTH FROM INTERVAL '2 years 13 months');
Result: 1
```

`quarter`

The quarter of the year (1 - 4) that the date is in

```
SELECT EXTRACT(QUARTER FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 1
```

`second`

The seconds field, including fractional parts (0 - 59[1])

```
SELECT EXTRACT(SECOND FROM TIMESTAMP '2001-02-16 20:38:40');
Result: 40

SELECT EXTRACT(SECOND FROM TIME '17:12:28.5');
Result: 28.5
```

`timezone`

The time zone offset from UTC, measured in seconds. Positive values correspond to time zones east of UTC, negative values to zones west of UTC. (Technically, PostgreSQL uses UT1 because leap seconds are not handled.)

`timezone_hour`

The hour component of the time zone offset

`timezone_minute`

The minute component of the time zone offset

`week`

The number of the ISO 8601 week-numbering week of the year. By definition, ISO weeks start on Mondays and the first week of a year contains January 4 of that year. In other words, the first Thursday of a year is in week 1 of that year.

In the ISO week-numbering system, it is possible for early-January dates to be part of the 52nd or 53rd week of the previous year, and for late-December dates to be part of the first week of the next year. For example, `2005-01-01` is part of the 53rd week of year 2004, and `2006-01-01` is part of the 52nd week of year 2005, while `2012-12-31` is part of the first week of 2013. It's recommended to use the `isoyear` field together with `week` to get consistent results.

```
SELECT EXTRACT(WEEK FROM TIMESTAMP '2001-02-16 20:38:40');
```

60 if leap seconds are implemented by the operating system

Result: 7

year

The year field. Keep in mind there is no 0 AD, so subtracting BC years from AD years should be done with care.

```
SELECT EXTRACT(YEAR FROM TIMESTAMP '2001-02-16 20:38:40');
```
Result: 2001

The extract function is primarily intended for computational processing. For formatting date/time values for display, see Section 9.8.

The date_part function is modeled on the traditional Ingres equivalent to the SQL-standard function extract:

```
date_part('field', source)
```

Note that here the *field* parameter needs to be a string value, not a name. The valid field names for date_part are the same as for extract.

```
SELECT date_part('day', TIMESTAMP '2001-02-16 20:38:40');
Result: 16

SELECT date_part('hour', INTERVAL '4 hours 3 minutes');
Result: 4
```

9.9.2. date_trunc

The function date_trunc is conceptually similar to the trunc function for numbers.

```
date_trunc('field', source)
```

source is a value expression of type timestamp or interval. (Values of type date and time are cast automatically to timestamp or interval, respectively.) *field* selects to which precision to truncate the input value. The return value is of type timestamp or interval with all fields that are less significant than the selected one set to zero (or one, for day and month).

Valid values for *field* are:

```
microseconds
milliseconds
second
minute
hour
day
week
month
quarter
year
decade
century
millennium
```

Examples:

```
SELECT date_trunc('hour', TIMESTAMP '2001-02-16 20:38:40');
Result: 2001-02-16 20:00:00

SELECT date_trunc('year', TIMESTAMP '2001-02-16 20:38:40');
Result: 2001-01-01 00:00:00
```

9.9.3. AT TIME ZONE

The `AT TIME ZONE` construct allows conversions of time stamps to different time zones. Table 9-29 shows its variants.

Table 9-29. AT TIME ZONE Variants

Expression	Return Type	Description
`timestamp without time zone AT TIME ZONE` *zone*	`timestamp with time zone`	Treat given time stamp *without time zone* as located in the specified time zone
`timestamp with time zone AT TIME ZONE` *zone*	`timestamp without time zone`	Convert given time stamp *with time zone* to the new time zone, with no time zone designation
`time with time zone AT TIME ZONE` *zone*	`time with time zone`	Convert given time *with time zone* to the new time zone

In these expressions, the desired time zone *zone* can be specified either as a text string (e.g., `'PST'`) or as an interval (e.g., `INTERVAL '-08:00'`). In the text case, a time zone name can be specified in any of the ways described in Section 8.5.3.

Examples (assuming the local time zone is `PST8PDT`):

```
SELECT TIMESTAMP '2001-02-16 20:38:40' AT TIME ZONE 'MST';
Result: 2001-02-16 19:38:40-08

SELECT TIMESTAMP WITH TIME ZONE '2001-02-16 20:38:40-05' AT TIME ZONE 'MST';
Result: 2001-02-16 18:38:40
```

The first example takes a time stamp without time zone and interprets it as MST time (UTC-7), which is then converted to PST (UTC-8) for display. The second example takes a time stamp specified in EST (UTC-5) and converts it to local time in MST (UTC-7).

The function `timezone(`*zone*`, `*timestamp*`)` is equivalent to the SQL-conforming construct *timestamp* `AT TIME ZONE` *zone*.

9.9.4. Current Date/Time

PostgreSQL provides a number of functions that return values related to the current date and time. These SQL-standard functions all return values based on the start time of the current transaction:

```
CURRENT_DATE
CURRENT_TIME
```

```
CURRENT_TIMESTAMP
CURRENT_TIME(precision)
CURRENT_TIMESTAMP(precision)
LOCALTIME
LOCALTIMESTAMP
LOCALTIME(precision)
LOCALTIMESTAMP(precision)
```

`CURRENT_TIME` and `CURRENT_TIMESTAMP` deliver values with time zone; `LOCALTIME` and `LOCALTIMESTAMP` deliver values without time zone.

`CURRENT_TIME`, `CURRENT_TIMESTAMP`, `LOCALTIME`, and `LOCALTIMESTAMP` can optionally take a precision parameter, which causes the result to be rounded to that many fractional digits in the seconds field. Without a precision parameter, the result is given to the full available precision.

Some examples:

```
SELECT CURRENT_TIME;
Result: 14:39:53.662522-05

SELECT CURRENT_DATE;
Result: 2001-12-23

SELECT CURRENT_TIMESTAMP;
Result: 2001-12-23 14:39:53.662522-05

SELECT CURRENT_TIMESTAMP(2);
Result: 2001-12-23 14:39:53.66-05

SELECT LOCALTIMESTAMP;
Result: 2001-12-23 14:39:53.662522
```

Since these functions return the start time of the current transaction, their values do not change during the transaction. This is considered a feature: the intent is to allow a single transaction to have a consistent notion of the "current" time, so that multiple modifications within the same transaction bear the same time stamp.

> **Note:** Other database systems might advance these values more frequently.

PostgreSQL also provides functions that return the start time of the current statement, as well as the actual current time at the instant the function is called. The complete list of non-SQL-standard time functions is:

```
transaction_timestamp()
statement_timestamp()
clock_timestamp()
timeofday()
now()
```

`transaction_timestamp()` is equivalent to `CURRENT_TIMESTAMP`, but is named to clearly reflect what it returns. `statement_timestamp()` returns the start time of the current

statement (more specifically, the time of receipt of the latest command message from the client). `statement_timestamp()` and `transaction_timestamp()` return the same value during the first command of a transaction, but might differ during subsequent commands. `clock_timestamp()` returns the actual current time, and therefore its value changes even within a single SQL command. `timeofday()` is a historical PostgreSQL function. Like `clock_timestamp()`, it returns the actual current time, but as a formatted `text` string rather than a `timestamp with time zone` value. `now()` is a traditional PostgreSQL equivalent to `transaction_timestamp()`.

All the date/time data types also accept the special literal value `now` to specify the current date and time (again, interpreted as the transaction start time). Thus, the following three all return the same result:

```
SELECT CURRENT_TIMESTAMP;
SELECT now();
SELECT TIMESTAMP 'now';  -- incorrect for use with DEFAULT
```

> **Tip:** You do not want to use the third form when specifying a `DEFAULT` clause while creating a table. The system will convert `now` to a `timestamp` as soon as the constant is parsed, so that when the default value is needed, the time of the table creation would be used! The first two forms will not be evaluated until the default value is used, because they are function calls. Thus they will give the desired behavior of defaulting to the time of row insertion.

9.9.5. Delaying Execution

The following functions are available to delay execution of the server process:

```
pg_sleep(seconds)
pg_sleep_for(interval)
pg_sleep_until(timestamp with time zone)
```

`pg_sleep` makes the current session's process sleep until *`seconds`* seconds have elapsed. *`seconds`* is a value of type `double precision`, so fractional-second delays can be specified. `pg_sleep_for` is a convenience function for larger sleep times specified as an `interval`. `pg_sleep_until` is a convenience function for when a specific wake-up time is desired. For example:

```
SELECT pg_sleep(1.5);
SELECT pg_sleep_for('5 minutes');
SELECT pg_sleep_until('tomorrow 03:00');
```

> **Note:** The effective resolution of the sleep interval is platform-specific; 0.01 seconds is a common value. The sleep delay will be at least as long as specified. It might be longer depending on factors such as server load. In particular, `pg_sleep_until` is not guaranteed to wake up exactly at the specified time, but it will not wake up any earlier.

> **Warning**
>
> Make sure that your session does not hold more locks than necessary when calling `pg_sleep` or its variants. Otherwise other sessions might have to wait for your sleeping process, slowing down the entire system.

9.10. Enum Support Functions

For enum types (described in Section 8.7), there are several functions that allow cleaner programming without hard-coding particular values of an enum type. These are listed in Table 9-30. The examples assume an enum type created as:

```
CREATE TYPE rainbow AS ENUM ('red', 'orange', 'yellow', 'green', 'blue', 'purple');
```

Table 9-30. Enum Support Functions

Function	Description	Example	Example Result
`enum_first(anyenum)`	Returns the first value of the input enum type	`enum_first(null::rainbow)`	`red`
`enum_last(anyenum)`	Returns the last value of the input enum type	`enum_last(null::rainbow)`	`purple`
`enum_range(anyenum)`	Returns all values of the input enum type in an ordered array	`enum_range(null::rainbow)`	`{red,orange,yellow,green,blue,p`
`enum_range(anyenum, anyenum)`	Returns the range between the two given enum values, as an ordered array. The values must be from the same enum type. If the first parameter is null, the result will start with the first value of the enum type. If the second parameter is null, the result will end with the last value of the enum type.	`enum_range('orange'::rainbow, 'green'::rainbow)`	`{orange,yellow,green}`
		`enum_range(NULL, 'green'::rainbow)`	`{red,orange,yellow,green}`
		`enum_range('orange'::rainbow, NULL)`	`{orange,yellow,green,blue,purpl`

Notice that except for the two-argument form of `enum_range`, these functions disregard the specific value passed to them; they care only about its declared data type. Either null or a specific value of the type can be passed, with the same result. It is more common to apply these functions to a table column or function argument than to a hardwired type name as suggested by the examples.

9.11. Geometric Functions and Operators

The geometric types `point`, `box`, `lseg`, `line`, `path`, `polygon`, and `circle` have a large set of native support functions and operators, shown in Table 9-31, Table 9-32, and Table 9-33.

> **Caution**
>
> Note that the "same as" operator, `~=`, represents the usual notion of equality for the `point`, `box`, `polygon`, and `circle` types. Some of these types also have an `=` operator, but `=` compares for equal *areas* only. The other scalar comparison operators (`<=` and so on) likewise compare areas for these types.

Table 9-31. Geometric Operators

Operator	Description	Example
`+`	Translation	`box '((0,0),(1,1))' + point '(2.0,0)'`
`-`	Translation	`box '((0,0),(1,1))' - point '(2.0,0)'`
`*`	Scaling/rotation	`box '((0,0),(1,1))' * point '(2.0,0)'`
`/`	Scaling/rotation	`box '((0,0),(2,2))' / point '(2.0,0)'`
`#`	Point or box of intersection	`'((1,-1),(-1,1))' # '((1,1),(-1,-1))'`
`#`	Number of points in path or polygon	`# '((1,0),(0,1),(-1,0))'`
`@-@`	Length or circumference	`@-@ path '((0,0),(1,0))'`
`@@`	Center	`@@ circle '((0,0),10)'`
`##`	Closest point to first operand on second operand	`point '(0,0)' ## lseg '((2,0),(0,2))'`
`<->`	Distance between	`circle '((0,0),1)' <-> circle '((5,0),1)'`
`&&`	Overlaps? (One point in common makes this true.)	`box '((0,0),(1,1))' && box '((0,0),(2,2))'`
`<<`	Is strictly left of?	`circle '((0,0),1)' << circle '((5,0),1)'`
`>>`	Is strictly right of?	`circle '((5,0),1)' >> circle '((0,0),1)'`
`&<`	Does not extend to the right of?	`box '((0,0),(1,1))' &< box '((0,0),(2,2))'`
`&>`	Does not extend to the left of?	`box '((0,0),(3,3))' &> box '((0,0),(2,2))'`
`<<|`	Is strictly below?	`box '((0,0),(3,3))' <<| box '((3,4),(5,5))'`
`|>>`	Is strictly above?	`box '((3,4),(5,5))' |>> box '((0,0),(3,3))'`

Operator	Description	Example
&<|	Does not extend above?	box '((0,0),(1,1))' &<| box '((0,0),(2,2))'
|&>	Does not extend below?	box '((0,0),(3,3))' |&> box '((0,0),(2,2))'
<^	Is below (allows touching)?	circle '((0,0),1)' <^ circle '((0,5),1)'
>^	Is above (allows touching)?	circle '((0,5),1)' >^ circle '((0,0),1)'
?#	Intersects?	lseg '((-1,0),(1,0))' ?# box '((-2,-2),(2,2))'
?-	Is horizontal?	?- lseg '((-1,0),(1,0))'
?-	Are horizontally aligned?	point '(1,0)' ?- point '(0,0)'
?|	Is vertical?	?| lseg '((-1,0),(1,0))'
?|	Are vertically aligned?	point '(0,1)' ?| point '(0,0)'
?-|	Is perpendicular?	lseg '((0,0),(0,1))' ?-| lseg '((0,0),(1,0))'
?||	Are parallel?	lseg '((-1,0),(1,0))' ?|| lseg '((-1,2),(1,2))'
@>	Contains?	circle '((0,0),2)' @> point '(1,1)'
<@	Contained in or on?	point '(1,1)' <@ circle '((0,0),2)'
~=	Same as?	polygon '((0,0),(1,1))' ~= polygon '((1,1),(0,0))'

Note: Before PostgreSQL 8.2, the containment operators @> and <@ were respectively called ~ and @. These names are still available, but are deprecated and will eventually be removed.

Table 9-32. Geometric Functions

Function	Return Type	Description	Example
area(*object*)	double precision	area	area(box '((0,0),(1,1))')
center(*object*)	point	center	center(box '((0,0),(1,2))')
diameter(circle)	double precision	diameter of circle	diameter(circle '((0,0),2.0)')

Function	Return Type	Description	Example
height(box)	double precision	vertical size of box	height(box '((0,0),(1,1))')
isclosed(path)	boolean	a closed path?	isclosed(path '((0,0),(1,1),(2,0))')
isopen(path)	boolean	an open path?	isopen(path '[(0,0),(1,1),(2,0)]')
length(*object*)	double precision	length	length(path '((-1,0),(1,0))')
npoints(path)	int	number of points	npoints(path '[(0,0),(1,1),(2,0)]')
npoints(polygon)	int	number of points	npoints(polygon '((1,1),(0,0))')
pclose(path)	path	convert path to closed	pclose(path '[(0,0),(1,1),(2,0)]')
popen(path)	path	convert path to open	popen(path '((0,0),(1,1),(2,0))')
radius(circle)	double precision	radius of circle	radius(circle '((0,0),2.0)')
width(box)	double precision	horizontal size of box	width(box '((0,0),(1,1))')

Table 9-33. Geometric Type Conversion Functions

Function	Return Type	Description	Example
box(circle)	box	circle to box	box(circle '((0,0),2.0)')
box(point, point)	box	points to box	box(point '(0,0)', point '(1,1)')
box(polygon)	box	polygon to box	box(polygon '((0,0),(1,1),(2,0))')
circle(box)	circle	box to circle	circle(box '((0,0),(1,1))')
circle(point, double precision)	circle	center and radius to circle	circle(point '(0,0)', 2.0)
circle(polygon)	circle	polygon to circle	circle(polygon '((0,0),(1,1),(2,0))')

Function	Return Type	Description	Example
line(point, point)	line	points to line	line(point '(-1,0)', point '(1,0)')
lseg(box)	lseg	box diagonal to line segment	lseg(box '((-1,0),(1,0))')
lseg(point, point)	lseg	points to line segment	lseg(point '(-1,0)', point '(1,0)')
path(polygon)	path	polygon to path	path(polygon '((0,0),(1,1),(2,0))')
point(double precision, double precision)	point	construct point	point(23.4, -44.5)
point(box)	point	center of box	point(box '((-1,0),(1,0))')
point(circle)	point	center of circle	point(circle '((0,0),2.0)')
point(lseg)	point	center of line segment	point(lseg '((-1,0),(1,0))')
point(polygon)	point	center of polygon	point(polygon '((0,0),(1,1),(2,0))')
polygon(box)	polygon	box to 4-point polygon	polygon(box '((0,0),(1,1))')
polygon(circle)	polygon	circle to 12-point polygon	polygon(circle '((0,0),2.0)')
polygon(*npts*, circle)	polygon	circle to *npts*-point polygon	polygon(12, circle '((0,0),2.0)')
polygon(path)	polygon	path to polygon	polygon(path '((0,0),(1,1),(2,0))')

It is possible to access the two component numbers of a `point` as though the point were an array with indexes 0 and 1. For example, if `t.p` is a `point` column then `SELECT p[0] FROM t` retrieves the X coordinate and `UPDATE t SET p[1] = ...` changes the Y coordinate. In the same way, a value of type `box` or `lseg` can be treated as an array of two `point` values.

The `area` function works for the types `box`, `circle`, and `path`. The `area` function only works on the `path` data type if the points in the `path` are non-intersecting. For example, the `path '((0,0),(0,1),(2,1),(2,2),(1,2),(1,0),(0,0))'::PATH` will not work; however, the following visually identical `path '((0,0),(0,1),(1,1),(1,2),(2,2),(2,1),(1,1),(1,0),(0,0))'::PATH` will work. If the concept of an intersecting versus non-intersecting `path` is confusing, draw both of the above `path`s side by side on a piece of graph paper.

9.12. Network Address Functions and Operators

Table 9-34 shows the operators available for the `cidr` and `inet` types. The operators <<, <<=, >>, >>=, and && test for subnet inclusion. They consider only the network parts of the two addresses (ignoring any host part) and determine whether one network is identical to or a subnet of the other.

Table 9-34. `cidr` and `inet` Operators

Operator	Description	Example
<	is less than	`inet '192.168.1.5' < inet '192.168.1.6'`
<=	is less than or equal	`inet '192.168.1.5' <= inet '192.168.1.5'`
=	equals	`inet '192.168.1.5' = inet '192.168.1.5'`
>=	is greater or equal	`inet '192.168.1.5' >= inet '192.168.1.5'`
>	is greater than	`inet '192.168.1.5' > inet '192.168.1.4'`
<>	is not equal	`inet '192.168.1.5' <> inet '192.168.1.4'`
<<	is contained by	`inet '192.168.1.5' << inet '192.168.1/24'`
<<=	is contained by or equals	`inet '192.168.1/24' <<= inet '192.168.1/24'`
>>	contains	`inet '192.168.1/24' >> inet '192.168.1.5'`
>>=	contains or equals	`inet '192.168.1/24' >>= inet '192.168.1/24'`
&&	contains or is contained by	`inet '192.168.1/24' && inet '192.168.1.80/28'`
~	bitwise NOT	`~ inet '192.168.1.6'`
&	bitwise AND	`inet '192.168.1.6' & inet '0.0.0.255'`
|	bitwise OR	`inet '192.168.1.6' | inet '0.0.0.255'`
+	addition	`inet '192.168.1.6' + 25`
-	subtraction	`inet '192.168.1.43' - 36`
-	subtraction	`inet '192.168.1.43' - inet '192.168.1.19'`

Table 9-35 shows the functions available for use with the `cidr` and `inet` types. The `abbrev`, `host`, and `text` functions are primarily intended to offer alternative display formats.

Table 9-35. `cidr` and `inet` Functions

Function	Return Type	Description	Example	Result

Function	Return Type	Description	Example	Result
abbrev(inet)	text	abbreviated display format as text	abbrev(inet '10.1.0.0/16')	10.1.0.0/16
abbrev(cidr)	text	abbreviated display format as text	abbrev(cidr '10.1.0.0/16')	10.1/16
broadcast(inet)	inet	broadcast address for network	broadcast('192.168.1.5/24')	192.168.1.255/24
family(inet)	int	extract family of address; 4 for IPv4, 6 for IPv6	family('::1')	6
host(inet)	text	extract IP address as text	host('192.168.1.5/24')	192.168.1.5
hostmask(inet)	inet	construct host mask for network	hostmask('192.168.23.20/30')	0.0.0.3
masklen(inet)	int	extract netmask length	masklen('192.168.1.5/24')	24
netmask(inet)	inet	construct netmask for network	netmask('192.168.1.5/24')	255.255.255.0
network(inet)	cidr	extract network part of address	network('192.168.1.5/24')	192.168.1.0/24
set_masklen(inet, int)	inet	set netmask length for inet value	set_masklen('192.168.1.5/24', 16)	192.168.1.5/16
set_masklen(cidr, int)	cidr	set netmask length for cidr value	set_masklen('192.168.0.0/24'::cidr, 16)	192.168.0.0/16
text(inet)	text	extract IP address and netmask length as text	text(inet '192.168.1.5')	192.168.1.5/32

Any cidr value can be cast to inet implicitly or explicitly; therefore, the functions shown above as operating on inet also work on cidr values. (Where there are separate functions for inet and cidr, it is because the behavior should be different for the two cases.) Also, it is permitted to cast an inet value to cidr. When this is done, any bits to the right of the netmask are silently zeroed to create a valid cidr value. In addition, you can cast a text value to inet or cidr using normal casting syntax: for example, inet(*expression*) or *colname*::cidr.

Table 9-36 shows the functions available for use with the macaddr type. The function trunc(macaddr) returns a MAC address with the last 3 bytes set to zero. This can be used to associate the remaining prefix with a manufacturer.

Table 9-36. macaddr Functions

Function	Return Type	Description	Example	Result
trunc(macaddr)	macaddr	set last 3 bytes to zero	trunc(macaddr '12:34:56:78:90:ab')	12:34:56:00:00:00

The macaddr type also supports the standard relational operators (>, <=, etc.) for lexicographical ordering, and the bitwise arithmetic operators (~, & and |) for NOT, AND and OR.

9.13. Text Search Functions and Operators

Table 9-37, Table 9-38 and Table 9-39 summarize the functions and operators that are provided for full text searching. See Chapter 12 for a detailed explanation of PostgreSQL's text search facility.

Table 9-37. Text Search Operators

Operator	Description	Example	Result
@@	tsvector matches tsquery ?	to_tsvector('fat cats ate rats') @@ to_tsquery('cat & rat')	t
@@@	deprecated synonym for @@	to_tsvector('fat cats ate rats') @@@ to_tsquery('cat & rat')	t
||	concatenate tsvectors	'a:1 b:2'::tsvector || 'c:1 d:2 b:3'::tsvector	'a':1 'b':2,5 'c':3 'd':4
&&	AND tsquerys together	'fat | rat'::tsquery && 'cat'::tsquery	('fat' | 'rat') & 'cat'
||	OR tsquerys together	'fat | rat'::tsquery || 'cat'::tsquery	('fat' | 'rat') | 'cat'
!!	negate a tsquery	!! 'cat'::tsquery	!'cat'
@>	tsquery contains another ?	'cat'::tsquery @> 'cat & rat'::tsquery	f
<@	tsquery is contained in ?	'cat'::tsquery <@ 'cat & rat'::tsquery	t

Note: The tsquery containment operators consider only the lexemes listed in the two queries, ignoring the combining operators.

In addition to the operators shown in the table, the ordinary B-tree comparison operators (=, <, etc) are defined for types tsvector and tsquery. These are not very useful for text searching but allow, for example, unique indexes to be built on columns of these types.

Table 9-38. Text Search Functions

Function	Return Type	Description	Example	Result
get_current_ts_config()	regconfig	get default text search configuration	get_current_ts_config()	english
length(tsvector)	integer	number of lexemes in tsvector	length('fat:2,4 cat:3 rat:5A'::tsvector)	3
numnode(tsquery)	integer	number of lexemes plus operators in tsquery	numnode('(fat & rat) | cat'::tsquery)	5
plainto_tsquery([*config* regconfig ,] *query* text)	tsquery	produce tsquery ignoring punctuation	plainto_tsquery('fat rat' 'The Fat Rats')	'fat' & 'rat'
querytree(*query* tsquery)	text	get indexable part of a tsquery	querytree('foo & ! bar'::tsquery)	'foo'
setweight(tsvector, "char")	tsvector	assign weight to each element of tsvector	setweight('fat:2,4 cat:3 rat:5B'::tsvector, 'A')	'cat':3A 'fat':2A,4A 'rat':5A
strip(tsvector)	tsvector	remove positions and weights from tsvector	strip('fat:2,4 cat:3 rat:5A'::tsvector)	'cat' 'fat' 'rat'
to_tsquery([*config* regconfig ,] *query* text)	tsquery	normalize words and convert to tsquery	to_tsquery('english', 'The & Fat & Rats')	'fat' & 'rat'
to_tsvector([*config* regconfig ,] *document* text)	tsvector	reduce document text to tsvector	to_tsvector('english', 'The Fat Rats')	'fat':2 'rat':3
ts_headline([*config* regconfig,] *document* text, *query* tsquery [, *options* text])	text	display a query match	ts_headline('x y z', 'z'::tsquery)	x y z

Function	Return Type	Description	Example	Result
ts_rank([*weights* float4[],] *vector* tsvector, *query* tsquery [, *normalization* integer])	float4	rank document for query	ts_rank(textsearch, query)	0.818
ts_rank_cd([*weights* float4[],] *vector* tsvector, *query* tsquery [, *normalization* integer])	float4	rank document for query using cover density	ts_rank_cd('{0.1, 0.2, 0.4, 1.0}', textsearch, query)	2.01317
ts_rewrite(*query* tsquery, *target* tsquery, *substitute* tsquery)	tsquery	replace target with substitute within query	ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'foo|bar'::tsquery)	'b' & ('foo' | 'bar')
ts_rewrite(*query* tsquery, *select* text)	tsquery	replace using targets and substitutes from a SELECT command	SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases')	'b' & ('foo' | 'bar')
tsvector_update_trigger()	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger(tsvcol, 'pg_catalog.swedish', title, body)	
tsvector_update_trigger_column()	trigger	trigger function for automatic tsvector column update	CREATE TRIGGER ... tsvector_update_trigger_column(tsvcol, configcol, title, body)	

Note: All the text search functions that accept an optional regconfig argument will use the configuration specified by default_text_search_config when that argument is omitted.

The functions in Table 9-39 are listed separately because they are not usually used in everyday text searching operations. They are helpful for development and debugging of new text search configurations.

Table 9-39. Text Search Debugging Functions

Function	Return Type	Description	Example	Result
ts_debug([*config* regconfig,] *document* text, OUT *alias* text, OUT *description* text, OUT *token* text, OUT *dictionaries* regdictionary[], OUT *dictionary* regdictionary, OUT *lexemes* text[])	setof record	test a configuration	ts_debug('english', 'The Brightest supernovaes')	(asciiword,"Word, all ASCII",The,{english_stem},en ...
ts_lexize(*dict* regdictionary, *token* text)	text[]	test a dictionary	ts_lexize('english_stem', 'stars')	{star}
ts_parse(*parser_name* text, *document* text, OUT *tokid* integer, OUT *token* text)	setof record	test a parser	ts_parse('default', 'foo - bar')	(1,foo) ...
ts_parse(*parser_oid* oid, *document* text, OUT *tokid* integer, OUT *token* text)	setof record	test a parser	ts_parse(3722, 'foo - bar')	(1,foo) ...
ts_token_type(*parser_name* text, OUT *tokid* integer, OUT *alias* text, OUT *description* text)	setof record	get token types defined by parser	ts_token_type('default')	(1,asciiword,"Word, all ASCII") ...
ts_token_type(*parser_oid* oid, OUT *tokid* integer, OUT *alias* text, OUT *description* text)	setof record	get token types defined by parser	ts_token_type(3722)	(1,asciiword,"Word, all ASCII") ...
ts_stat(*sqlquery* text, [*weights* text,] OUT *word* text, OUT *ndoc* integer, OUT *nentry* integer)	setof record	get statistics of a tsvector column	ts_stat('SELECT vector from apod')	(foo,10,15) ...

9.14. XML Functions

The functions and function-like expressions described in this section operate on values of type `xml`. Check Section 8.13 for information about the `xml` type. The function-like expressions `xmlparse` and `xmlserialize` for converting to and from type `xml` are not repeated here. Use of most of these functions requires the installation to have been built with `configure --with-libxml`.

9.14.1. Producing XML Content

A set of functions and function-like expressions are available for producing XML content from SQL data. As such, they are particularly suitable for formatting query results into XML documents for processing in client applications.

9.14.1.1. `xmlcomment`

`xmlcomment(`*`text`*`)`

The function `xmlcomment` creates an XML value containing an XML comment with the specified text as content. The text cannot contain "`--`" or end with a "`-`" so that the resulting construct is a valid XML comment. If the argument is null, the result is null.

Example:

```
SELECT xmlcomment('hello');

  xmlcomment
--------------
 <!--hello-->
```

9.14.1.2. `xmlconcat`

`xmlconcat(`*`xml`*`[, ...])`

The function `xmlconcat` concatenates a list of individual XML values to create a single value containing an XML content fragment. Null values are omitted; the result is only null if there are no nonnull arguments.

Example:

```
SELECT xmlconcat('<abc/>', '<bar>foo</bar>');

      xmlconcat
----------------------
 <abc/><bar>foo</bar>
```

XML declarations, if present, are combined as follows. If all argument values have the same XML version declaration, that version is used in the result, else no version is used. If all argument values have the standalone declaration value "yes", then that value is used in the result. If all argument values have a standalone declaration value and at least one is "no", then that is used in the result. Else the result will have no standalone declaration. If the result is determined to require a standalone

declaration but no version declaration, a version declaration with version 1.0 will be used because XML requires an XML declaration to contain a version declaration. Encoding declarations are ignored and removed in all cases.

Example:

```
SELECT xmlconcat('<?xml version="1.1"?><foo/>', '<?xml version="1.1" standalone="no"?><b

             xmlconcat
----------------------------------
 <?xml version="1.1"?><foo/><bar/>
```

9.14.1.3. `xmlelement`

```
xmlelement(name name [, xmlattributes(value [AS attname] [, ... ])] [, content, ...])
```

The `xmlelement` expression produces an XML element with the given name, attributes, and content.

Examples:

```
SELECT xmlelement(name foo);

 xmlelement
------------
 <foo/>

SELECT xmlelement(name foo, xmlattributes('xyz' as bar));

    xmlelement
------------------
 <foo bar="xyz"/>

SELECT xmlelement(name foo, xmlattributes(current_date as bar), 'cont', 'ent');

             xmlelement
-------------------------------------
 <foo bar="2007-01-26">content</foo>
```

Element and attribute names that are not valid XML names are escaped by replacing the offending characters by the sequence _x*HHHH*_, where *HHHH* is the character's Unicode codepoint in hexadecimal notation. For example:

```
SELECT xmlelement(name "foo$bar", xmlattributes('xyz' as "a&b"));

            xmlelement
----------------------------------
 <foo_x0024_bar a_x0026_b="xyz"/>
```

An explicit attribute name need not be specified if the attribute value is a column reference, in which case the column's name will be used as the attribute name by default. In other cases, the attribute must be given an explicit name. So this example is valid:

```
CREATE TABLE test (a xml, b xml);
SELECT xmlelement(name test, xmlattributes(a, b)) FROM test;
```

But these are not:

```
SELECT xmlelement(name test, xmlattributes('constant'), a, b) FROM test;
SELECT xmlelement(name test, xmlattributes(func(a, b))) FROM test;
```

Element content, if specified, will be formatted according to its data type. If the content is itself of type `xml`, complex XML documents can be constructed. For example:

```
SELECT xmlelement(name foo, xmlattributes('xyz' as bar),
                            xmlelement(name abc),
                            xmlcomment('test'),
                            xmlelement(name xyz));

                  xmlelement
----------------------------------------------
 <foo bar="xyz"><abc/><!--test--><xyz/></foo>
```

Content of other types will be formatted into valid XML character data. This means in particular that the characters <, >, and & will be converted to entities. Binary data (data type `bytea`) will be represented in base64 or hex encoding, depending on the setting of the configuration parameter xmlbinary. The particular behavior for individual data types is expected to evolve in order to align the SQL and PostgreSQL data types with the XML Schema specification, at which point a more precise description will appear.

9.14.1.4. `xmlforest`

```
xmlforest(content [AS name] [, ...])
```

The `xmlforest` expression produces an XML forest (sequence) of elements using the given names and content.

Examples:

```
SELECT xmlforest('abc' AS foo, 123 AS bar);

          xmlforest
------------------------------
 <foo>abc</foo><bar>123</bar>


SELECT xmlforest(table_name, column_name)
FROM information_schema.columns
WHERE table_schema = 'pg_catalog';

                                        xmlforest
-----------------------------------------------------------------------------------------
 <table_name>pg_authid</table_name><column_name>rolname</column_name>
 <table_name>pg_authid</table_name><column_name>rolsuper</column_name>
 ...
```

As seen in the second example, the element name can be omitted if the content value is a column reference, in which case the column name is used by default. Otherwise, a name must be specified.

Element names that are not valid XML names are escaped as shown for xmlelement above. Similarly, content data is escaped to make valid XML content, unless it is already of type xml.

Note that XML forests are not valid XML documents if they consist of more than one element, so it might be useful to wrap xmlforest expressions in xmlelement.

9.14.1.5. xmlpi

```
xmlpi(name target [, content])
```

The xmlpi expression creates an XML processing instruction. The content, if present, must not contain the character sequence ?>.

Example:

```
SELECT xmlpi(name php, 'echo "hello world";');

            xmlpi
-----------------------------
 <?php echo "hello world";?>
```

9.14.1.6. xmlroot

```
xmlroot(xml, version text | no value [, standalone yes|no|no value])
```

The xmlroot expression alters the properties of the root node of an XML value. If a version is specified, it replaces the value in the root node's version declaration; if a standalone setting is specified, it replaces the value in the root node's standalone declaration.

```
SELECT xmlroot(xmlparse(document '<?xml version="1.1"?><content>abc</content>'),
               version '1.0', standalone yes);

                xmlroot
----------------------------------------
 <?xml version="1.0" standalone="yes"?>
 <content>abc</content>
```

9.14.1.7. xmlagg

```
xmlagg(xml)
```

The function xmlagg is, unlike the other functions described here, an aggregate function. It concatenates the input values to the aggregate function call, much like xmlconcat does, except that concatenation occurs across rows rather than across expressions in a single row. See Section 9.20 for additional information about aggregate functions.

Example:

```
CREATE TABLE test (y int, x xml);
INSERT INTO test VALUES (1, '<foo>abc</foo>');
```

```
INSERT INTO test VALUES (2, '<bar/>');
SELECT xmlagg(x) FROM test;
        xmlagg
----------------------
 <foo>abc</foo><bar/>
```

To determine the order of the concatenation, an `ORDER BY` clause may be added to the aggregate call as described in Section 4.2.7. For example:

```
SELECT xmlagg(x ORDER BY y DESC) FROM test;
        xmlagg
----------------------
 <bar/><foo>abc</foo>
```

The following non-standard approach used to be recommended in previous versions, and may still be useful in specific cases:

```
SELECT xmlagg(x) FROM (SELECT * FROM test ORDER BY y DESC) AS tab;
        xmlagg
----------------------
 <bar/><foo>abc</foo>
```

9.14.2. XML Predicates

The expressions described in this section check properties of `xml` values.

9.14.2.1. IS DOCUMENT

```
xml IS DOCUMENT
```

The expression `IS DOCUMENT` returns true if the argument XML value is a proper XML document, false if it is not (that is, it is a content fragment), or null if the argument is null. See Section 8.13 about the difference between documents and content fragments.

9.14.2.2. XMLEXISTS

```
XMLEXISTS(text PASSING [BY REF] xml [BY REF])
```

The function `xmlexists` returns true if the XPath expression in the first argument returns any nodes, and false otherwise. (If either argument is null, the result is null.)

Example:

```
SELECT xmlexists('//town[text() = "Toronto"]' PASSING BY REF '<towns><town>Toronto</town

 xmlexists
------------
 t
```

```
(1 row)
```

The BY REF clauses have no effect in PostgreSQL, but are allowed for SQL conformance and compatibility with other implementations. Per SQL standard, the first BY REF is required, the second is optional. Also note that the SQL standard specifies the xmlexists construct to take an XQuery expression as first argument, but PostgreSQL currently only supports XPath, which is a subset of XQuery.

9.14.2.3. xml_is_well_formed

```
xml_is_well_formed(text)
xml_is_well_formed_document(text)
xml_is_well_formed_content(text)
```

These functions check whether a text string is well-formed XML, returning a Boolean result. xml_is_well_formed_document checks for a well-formed document, while xml_is_well_formed_content checks for well-formed content. xml_is_well_formed does the former if the xmloption configuration parameter is set to DOCUMENT, or the latter if it is set to CONTENT. This means that xml_is_well_formed is useful for seeing whether a simple cast to type xml will succeed, whereas the other two functions are useful for seeing whether the corresponding variants of XMLPARSE will succeed.

Examples:

```
SET xmloption TO DOCUMENT;
SELECT xml_is_well_formed('<>');
 xml_is_well_formed
--------------------
 f
(1 row)

SELECT xml_is_well_formed('<abc/>');
 xml_is_well_formed
--------------------
 t
(1 row)

SET xmloption TO CONTENT;
SELECT xml_is_well_formed('abc');
 xml_is_well_formed
--------------------
 t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</
 xml_is_well_formed_document
-----------------------------
 t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</
 xml_is_well_formed_document
-----------------------------
 f
```

```
(1 row)
```

The last example shows that the checks include whether namespaces are correctly matched.

9.14.3. Processing XML

To process values of data type `xml`, PostgreSQL offers the functions `xpath` and `xpath_exists`, which evaluate XPath 1.0 expressions.

```
xpath(xpath, xml [, nsarray])
```

The function `xpath` evaluates the XPath expression *`xpath`* (a `text` value) against the XML value *`xml`*. It returns an array of XML values corresponding to the node set produced by the XPath expression. If the XPath expression returns a scalar value rather than a node set, a single-element array is returned.

The second argument must be a well formed XML document. In particular, it must have a single root node element.

The optional third argument of the function is an array of namespace mappings. This array should be a two-dimensional `text` array with the length of the second axis being equal to 2 (i.e., it should be an array of arrays, each of which consists of exactly 2 elements). The first element of each array entry is the namespace name (alias), the second the namespace URI. It is not required that aliases provided in this array be the same as those being used in the XML document itself (in other words, both in the XML document and in the `xpath` function context, aliases are *local*).

Example:

```
SELECT xpath('/my:a/text()', '<my:a xmlns:my="http://example.com">test</my:a>',
             ARRAY[ARRAY['my', 'http://example.com']]);

 xpath
--------
 {test}
(1 row)
```

To deal with default (anonymous) namespaces, do something like this:

```
SELECT xpath('//mydefns:b/text()', '<a xmlns="http://example.com"><b>test</b></a>',
             ARRAY[ARRAY['mydefns', 'http://example.com']]);

 xpath
--------
 {test}
(1 row)
```

```
xpath_exists(xpath, xml [, nsarray])
```

The function `xpath_exists` is a specialized form of the `xpath` function. Instead of returning the individual XML values that satisfy the XPath, this function returns a Boolean indicating whether the query was satisfied or not. This function is equivalent to the standard `XMLEXISTS` predicate, except that it also offers support for a namespace mapping argument.

Example:

```
SELECT xpath_exists('/my:a/text()', '<my:a xmlns:my="http://example.com">test</my:a>',
                    ARRAY[ARRAY['my', 'http://example.com']]);

 xpath_exists
--------------
 t
(1 row)
```

9.14.4. Mapping Tables to XML

The following functions map the contents of relational tables to XML values. They can be thought of as XML export functionality:

```
table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xml(query text, nulls boolean, tableforest boolean, targetns text)
cursor_to_xml(cursor refcursor, count int, nulls boolean,
              tableforest boolean, targetns text)
```

The return type of each function is `xml`.

`table_to_xml` maps the content of the named table, passed as parameter `tbl`. The `regclass` type accepts strings identifying tables using the usual notation, including optional schema qualifications and double quotes. `query_to_xml` executes the query whose text is passed as parameter `query` and maps the result set. `cursor_to_xml` fetches the indicated number of rows from the cursor specified by the parameter `cursor`. This variant is recommended if large tables have to be mapped, because the result value is built up in memory by each function.

If `tableforest` is false, then the resulting XML document looks like this:

```
<tablename>
  <row>
    <columnname1>data</columnname1>
    <columnname2>data</columnname2>
  </row>

  <row>
    ...
  </row>

  ...
</tablename>
```

If `tableforest` is true, the result is an XML content fragment that looks like this:

```
<tablename>
  <columnname1>data</columnname1>
  <columnname2>data</columnname2>
</tablename>

<tablename>
  ...
</tablename>
```

...

If no table name is available, that is, when mapping a query or a cursor, the string `table` is used in the first format, `row` in the second format.

The choice between these formats is up to the user. The first format is a proper XML document, which will be important in many applications. The second format tends to be more useful in the `cursor_to_xml` function if the result values are to be reassembled into one document later on. The functions for producing XML content discussed above, in particular `xmlelement`, can be used to alter the results to taste.

The data values are mapped in the same way as described for the function `xmlelement` above.

The parameter `nulls` determines whether null values should be included in the output. If true, null values in columns are represented as:

```
<columnname xsi:nil="true"/>
```

where `xsi` is the XML namespace prefix for XML Schema Instance. An appropriate namespace declaration will be added to the result value. If false, columns containing null values are simply omitted from the output.

The parameter `targetns` specifies the desired XML namespace of the result. If no particular namespace is wanted, an empty string should be passed.

The following functions return XML Schema documents describing the mappings performed by the corresponding functions above:

```
table_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xmlschema(query text, nulls boolean, tableforest boolean, targetns text)
cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text)
```

It is essential that the same parameters are passed in order to obtain matching XML data mappings and XML Schema documents.

The following functions produce XML data mappings and the corresponding XML Schema in one document (or forest), linked together. They can be useful where self-contained and self-describing results are wanted:

```
table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns te
query_to_xml_and_xmlschema(query text, nulls boolean, tableforest boolean, targetns text
```

In addition, the following functions are available to produce analogous mappings of entire schemas or the entire current database:

```
schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns te

database_to_xml(nulls boolean, tableforest boolean, targetns text)
database_to_xmlschema(nulls boolean, tableforest boolean, targetns text)
database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text)
```

Note that these potentially produce a lot of data, which needs to be built up in memory. When requesting content mappings of large schemas or databases, it might be worthwhile to consider mapping the tables separately instead, possibly even through a cursor.

The result of a schema content mapping looks like this:

```
<schemaname>

table1-mapping

table2-mapping

...

</schemaname>
```

where the format of a table mapping depends on the `tableforest` parameter as explained above.

The result of a database content mapping looks like this:

```
<dbname>

<schema1name>
  ...
</schema1name>

<schema2name>
  ...
</schema2name>

...

</dbname>
```

where the schema mapping is as above.

As an example of using the output produced by these functions, Figure 9-1 shows an XSLT stylesheet that converts the output of `table_to_xml_and_xmlschema` to an HTML document containing a tabular rendition of the table data. In a similar manner, the results from these functions can be converted into other XML-based formats.

Figure 9-1. XSLT Stylesheet for Converting SQL/XML Output to HTML

```
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
    xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns="http://www.w3.org/1999/xhtml"
>

  <xsl:output method="xml"
      doctype-system="http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
      doctype-public="-//W3C/DTD XHTML 1.0 Strict//EN"
      indent="yes"/>

  <xsl:template match="/*">
    <xsl:variable name="schema" select="//xsd:schema"/>
    <xsl:variable name="tabletypename"
                  select="$schema/xsd:element[@name=name(current())]/@type"/>
    <xsl:variable name="rowtypename"
                  select="$schema/xsd:complexType[@name=$tabletypename]/xsd:sequence/xsd

    <html>
      <head>
```

```
        <title><xsl:value-of select="name(current())"/></title>
      </head>
      <body>
        <table>
          <tr>
            <xsl:for-each select="$schema/xsd:complexType[@name=$rowtypename]/xsd:sequen
              <th><xsl:value-of select="."/></th>
            </xsl:for-each>
          </tr>

          <xsl:for-each select="row">
            <tr>
              <xsl:for-each select="*">
                <td><xsl:value-of select="."/></td>
              </xsl:for-each>
            </tr>
          </xsl:for-each>
        </table>
      </body>
    </html>
  </xsl:template>

</xsl:stylesheet>
```

9.15. JSON Functions and Operators

Table 9-40 shows the operators that are available for use with the two JSON data types (see Section 8.14).

Table 9-40. `json` and `jsonb` Operators

Operator	Right Operand Type	Description	Example	Example Result
`->`	`int`	Get JSON array element (indexed from zero)	`'[{"a":"foo"},{"b":"bar"},{"c":"baz"}]'::js`	
`->`	`text`	Get JSON object field by key	`'{"a": {"b":"foo"}}'::json->'a'`	`{"b":"foo"}`
`->>`	`int`	Get JSON array element as `text`	`'[1,2,3]'::json->>2`	
`->>`	`text`	Get JSON object field as `text`	`'{"a":1,"b":2}'::json->>'b'`	
`#>`	`text[]`	Get JSON object at specified path	`'{"a": {"b":{"c": "foo"}}}'::json#>'{a,b}'`	`{"c": "foo"}`
`#>>`	`text[]`	Get JSON object at specified path as `text`	`'{"a":[1,2,3],"b":[4,5,6]}'::json#>>'{a,2}`	

Note: There are parallel variants of these operators for both the `json` and `jsonb` types. The field/element/path extraction operators return the same type as their left-hand input (either `json` or `jsonb`), except for those specified as returning `text`, which coerce the value to text. The field/element/path extraction operators return NULL, rather than failing, if the JSON input does not have the right structure to match the request; for example if no such element exists.

The standard comparison operators shown in Table 9-1 are available for `jsonb`, but not for `json`. They follow the ordering rules for B-tree operations outlined at Section 8.14.4.

Some further operators also exist only for `jsonb`, as shown in Table 9-41. Many of these operators can be indexed by `jsonb` operator classes. For a full description of `jsonb` containment and existence semantics, see Section 8.14.3. Section 8.14.4 describes how these operators can be used to effectively index `jsonb` data.

Table 9-41. Additional `jsonb` Operators

Operator	Right Operand Type	Description	Example
`@>`	`jsonb`	Does the left JSON value contain within it the right value?	`'{"a":1, "b":2}'::jsonb @> '{"b":2}'::jsonb`
`<@`	`jsonb`	Is the left JSON value contained within the right value?	`'{"b":2}'::jsonb <@ '{"a":1, "b":2}'::jsonb`
`?`	`text`	Does the key/element *string* exist within the JSON value?	`'{"a":1, "b":2}'::jsonb ? 'b'`
`?|`	`text[]`	Do any of these key/element *strings* exist?	`'{"a":1, "b":2, "c":3}'::jsonb ?| array['b', 'c']`
`?&`	`text[]`	Do all of these key/element *strings* exist?	`'["a", "b"]'::jsonb ?& array['a', 'b']`

Table 9-42 shows the functions that are available for creating `json` values. (Currently, there are no equivalent functions for `jsonb`, but you can cast the result of one of these functions to `jsonb`.)

Table 9-42. JSON Creation Functions

Function	Description	Example	Example Result

Function	Description	Example	Example Result
`to_json(anyelement)`	Returns the value as JSON. Arrays and composites are converted (recursively) to arrays and objects; otherwise, if there is a cast from the type to `json`, the cast function will be used to perform the conversion; otherwise, a JSON scalar value is produced. For any scalar type other than a number, a Boolean, or a null value, the text representation will be used, properly quoted and escaped so that it is a valid JSON string.	`to_json('Fred said "Hi."'::text)`	`"Fred said \"Hi.\""`
`array_to_json(anyarray [, pretty_bool])`	Returns the array as a JSON array. A PostgreSQL multidimensional array becomes a JSON array of arrays. Line feeds will be added between dimension-1 elements if `pretty_bool` is true.	`array_to_json('{{1,5},{99,100}}'::int[])`	`[[1,5],[99,100]]`
`row_to_json(record [, pretty_bool])`	Returns the row as a JSON object. Line feeds will be added between level-1 elements if `pretty_bool` is true.	`row_to_json(row(1,'foo'))`	`{"f1":1,"f2":"foo"}`
`json_build_array(VARIADIC "any")`	Builds a possibly-heterogeneously-typed JSON array out of a variadic argument list.	`json_build_array(1,2,'3',4,5)`	`[1, 2, "3", 4, 5]`
`json_build_object(VARIADIC "any")`	Builds a JSON object out of a variadic argument list. By convention, the argument list consists of alternating keys and values.	`json_build_object('foo',1,'bar',2)`	`{"foo": 1, "bar": 2}`

Function	Description	Example	Example Result
`json_object(text[])`	Builds a JSON object out of a text array. The array must have either exactly one dimension with an even number of members, in which case they are taken as alternating key/value pairs, or two dimensions such that each inner array has exactly two elements, which are taken as a key/value pair.	`json_object('{a, 1, b, "def", c, 3.5}')` `json_object('{{a, 1},{b, "def"},{c, 3.5}}')`	`{"a": "1", "b": "def", "c": "3.5"}`
`json_object(keys text[], values text[])`	This form of `json_object` takes keys and values pairwise from two separate arrays. In all other respects it is identical to the one-argument form.	`json_object('{a, b}', '{1,2}')`	`{"a": "1", "b": "2"}`

Note: `array_to_json` and `row_to_json` have the same behavior as `to_json` except for offering a pretty-printing option. The behavior described for `to_json` likewise applies to each individual value converted by the other JSON creation functions.

Note: The hstore extension has a cast from `hstore` to `json`, so that `hstore` values converted via the JSON creation functions will be represented as JSON objects, not as primitive string values.

Table 9-43 shows the functions that are available for processing `json` and `jsonb` values.

Table 9-43. JSON Processing Functions

Function	Return Type	Description	Example	Example Result
`json_array_length(json)` `jsonb_array_length(jsonb)`	`int`	Returns the number of elements in the outermost JSON array.	`json_array_length('[1,2,3,{"f1":1,"f2":[5,6]},4]')`	`5`

Function	Return Type	Description	Example	Example Result

`json_each(json)`
`jsonb_each(jsonb)`
	`setof key text, value json`
	`setof key text, value jsonb`
		Expands the outermost JSON object into a set of key/value pairs.	`select * from json_each('{"a":"foo", "b":"bar"}')`	`key | value`
				`-----`
				`a | "foo"`
				`b | "bar"`

`json_each_text(json)`
`jsonb_each_text(jsonb)`
	`setof key text, value text`	Expands the outermost JSON object into a set of key/value pairs. The returned values will be of type `text`.	`select * from json_each_text('{"a":"foo", "b":"bar"}')`	`key | value`
				`-----`
				`a | foo`
				`b | bar`

`json_extract_path(from_json json, VARIADIC path_elems text[])` `jsonb_extract_path(from_json jsonb, VARIADIC path_elems text[])`	`json` `jsonb`	Returns JSON value pointed to by *path_elems* (equivalent to `#>` operator).	`json_extract_path('{"f2":{"f3":1},"f4":{"f5":99,"f6":"foo"}}','f4')`	`{"f5":99,"f6":"foo"}`
`json_extract_path_text(from_json json, VARIADIC path_elems text[])` `jsonb_extract_path_text(from_json jsonb, VARIADIC path_elems text[])`	`text` `text`	Returns JSON value pointed to by *path_elems* as `text` (equivalent to `#>>` operator).	`json_extract_path_text('{"f2":{"f3":1},"f4":{"f5":99,"f6":"foo"}}','f4','f6')`	`foo`

`json_object_keys(json)`
`jsonb_object_keys(jsonb)`
	`setof text`
	`setof text`
		Returns set of keys in the outermost JSON object.	`json_object_keys('{"f1":"abc","f2":{"f3":"a", "f4":"b"}}')`	`json_object_keys`
				`------------------`
				`f1`
				`f2`

Function	Return Type	Description	Example	Example Result
`json_populate_record(base anyelement, from_json json)` `jsonb_populate_record(base anyelement, from_json jsonb)`	`anyelement`	Expands the object in *from_json* to a row whose columns match the record type defined by *base* (see note below).	`select * from json_populate_record(null::myrowtype, '{"a":1,"b":2}')`	`a | b` `1 | 2`

`json_populate_recordset(base anyelement, from_json json)`
`jsonb_populate_recordset(base anyelement, from_json jsonb)`
	`setof anyelement`	Expands the outermost array of objects in *from_json* to a set of rows whose columns match the record type defined by *base* (see note below).	`select * from json_populate_recordset(null::myrowtype, '[{"a":1,"b":2},{"a":3,"b":4}]')`	`a | b`
				`1 | 2`
				`3 | 4`

`json_array_elements(json)`
`jsonb_array_elements(jsonb)`
	`setof json`
	`setof jsonb`
		Expands a JSON array to a set of JSON values.	`select * from json_array_elements('[1,true, [2,false]]')`	`value`
				`1`
				`true`
				`[2,false]`

`json_array_elements_text(json)`
`jsonb_array_elements_text(jsonb)`
	`setof text`	Expands a JSON array to a set of `text` values.	`select * from json_array_elements_text('["foo", "bar"]')`	`value`
				`foo`
				`bar`

`json_typeof(json)` `jsonb_typeof(jsonb)`	`text`	Returns the type of the outermost JSON value as a text string. Possible types are `object`, `array`, `string`, `number`, `boolean`, and `null`.	`json_typeof('-123.4')`	`number`

Function	Return Type	Description	Example	Example Result
`json_to_record(json)` `jsonb_to_record(jsonb)`	`record`	Builds an arbitrary record from a JSON object (see note below). As with all functions returning `record`, the caller must explicitly define the structure of the record with an `AS` clause.	`select * from json_to_record('{"a":1,"b":[1,2,3],"c":"bar"}') as x(a int, b text, d text)`	`a | b | d` `1 | [1,2,3] |`
`json_to_recordset(json)` `jsonb_to_recordset(jsonb)`	`setof record`	Builds an arbitrary set of records from a JSON array of objects (see note below). As with all functions returning `record`, the caller must explicitly define the structure of the record with an `AS` clause.	`select * from json_to_recordset('[{"a":1,"b":"foo"},{"a"` `as x(a int, b text);`	`a | b` `1 | foo  2 |`

Note: Many of these functions and operators will convert Unicode escapes in JSON strings to the appropriate single character. This is a non-issue if the input is type `jsonb`, because the conversion was already done; but for `json` input, this may result in throwing an error, as noted in Section 8.14.

Note: In `json_populate_record`, `json_populate_recordset`, `json_to_record` and `json_to_recordset`, type coercion from the JSON is "best effort" and may not result in desired values for some types. JSON keys are matched to identical column names in the target row type. JSON fields that do not appear in the target row type will be omitted from the output, and target columns that do not match any JSON field will simply be NULL.

Note: The `json_typeof` function's `null` return value should not be confused with a SQL NULL. While calling `json_typeof('null'::json)` will return `null`, calling `json_typeof(NULL::json)` will return a SQL NULL.

See also Section 9.20 for the aggregate function `json_agg` which aggregates record values as JSON, and the aggregate function `json_object_agg` which aggregates pairs of values into a JSON object.

9.16. Sequence Manipulation Functions

This section describes functions for operating on *sequence objects*, also called sequence generators or just sequences. Sequence objects are special single-row tables created with CREATE SEQUENCE. Sequence objects are commonly used to generate unique identifiers for rows of a table. The sequence functions, listed in Table 9-44, provide simple, multiuser-safe methods for obtaining successive sequence values from sequence objects.

Table 9-44. Sequence Functions

Function	Return Type	Description
`currval(regclass)`	`bigint`	Return value most recently obtained with `nextval` for specified sequence
`lastval()`	`bigint`	Return value most recently obtained with `nextval` for any sequence
`nextval(regclass)`	`bigint`	Advance sequence and return new value
`setval(regclass, bigint)`	`bigint`	Set sequence's current value
`setval(regclass, bigint, boolean)`	`bigint`	Set sequence's current value and `is_called` flag

The sequence to be operated on by a sequence function is specified by a `regclass` argument, which is simply the OID of the sequence in the `pg_class` system catalog. You do not have to look up the OID by hand, however, since the `regclass` data type's input converter will do the work for you. Just write the sequence name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the sequence name. Thus:

```
nextval('foo')      operates on sequence foo
nextval('FOO')      operates on sequence foo
nextval('"Foo"')    operates on sequence Foo
```

The sequence name can be schema-qualified if necessary:

```
nextval('myschema.foo')     operates on myschema.foo
nextval('"myschema".foo')   same as above
nextval('foo')              searches search path for foo
```

See Section 8.18 for more information about `regclass`.

> **Note:** Before PostgreSQL 8.1, the arguments of the sequence functions were of type `text`, not `regclass`, and the above-described conversion from a text string to an OID value would happen at run time during each call. For backward compatibility, this facility still exists, but internally it is now handled as an implicit coercion from `text` to `regclass` before the function is invoked.
>
> When you write the argument of a sequence function as an unadorned literal string, it becomes a constant of type `regclass`. Since this is really just an OID, it will track the originally identified sequence despite later renaming, schema reassignment, etc. This "early binding" behavior is usually desirable for sequence references in column defaults and views. But sometimes you might want "late binding" where the sequence reference is resolved at run time. To get late-binding behavior, force the constant to be stored as a `text` constant instead of `regclass`:

```
nextval('foo'::text)      foo is looked up at runtime
```

Note that late binding was the only behavior supported in PostgreSQL releases before 8.1, so you might need to do this to preserve the semantics of old applications.

Of course, the argument of a sequence function can be an expression as well as a constant. If it is a text expression then the implicit coercion will result in a run-time lookup.

The available sequence functions are:

`nextval`

Advance the sequence object to its next value and return that value. This is done atomically: even if multiple sessions execute `nextval` concurrently, each will safely receive a distinct sequence value.

If a sequence object has been created with default parameters, successive `nextval` calls will return successive values beginning with 1. Other behaviors can be obtained by using special parameters in the CREATE SEQUENCE command; see its command reference page for more information.

> **Important:** To avoid blocking concurrent transactions that obtain numbers from the same sequence, a `nextval` operation is never rolled back; that is, once a value has been fetched it is considered used, even if the transaction that did the `nextval` later aborts. This means that aborted transactions might leave unused "holes" in the sequence of assigned values.

`currval`

Return the value most recently obtained by `nextval` for this sequence in the current session. (An error is reported if `nextval` has never been called for this sequence in this session.) Because this is returning a session-local value, it gives a predictable answer whether or not other sessions have executed `nextval` since the current session did.

`lastval`

Return the value most recently returned by `nextval` in the current session. This function is identical to `currval`, except that instead of taking the sequence name as an argument it fetches the value of the last sequence used by `nextval` in the current session. It is an error to call `lastval` if `nextval` has not yet been called in the current session.

`setval`

Reset the sequence object's counter value. The two-parameter form sets the sequence's `last_value` field to the specified value and sets its `is_called` field to `true`, meaning that the next `nextval` will advance the sequence before returning a value. The value reported by `currval` is also set to the specified value. In the three-parameter form, `is_called` can be set to either `true` or `false`. `true` has the same effect as the two-parameter form. If it is set to `false`, the next `nextval` will return exactly the specified value, and sequence advancement commences with the following `nextval`. Furthermore, the value reported by `currval` is not changed in this case. For example,

```
SELECT setval('foo', 42);           Next nextval will return 43
SELECT setval('foo', 42, true);     Same as above
SELECT setval('foo', 42, false);    Next nextval will return 42
```

The result returned by `setval` is just the value of its second argument.

Important: Because sequences are non-transactional, changes made by `setval` are not undone if the transaction rolls back.

9.17. Conditional Expressions

This section describes the SQL-compliant conditional expressions available in PostgreSQL.

Tip: If your needs go beyond the capabilities of these conditional expressions, you might want to consider writing a stored procedure in a more expressive programming language.

9.17.1. CASE

The SQL `CASE` expression is a generic conditional expression, similar to if/else statements in other programming languages:

```
CASE WHEN condition THEN result
     [WHEN ...]
     [ELSE result]
END
```

`CASE` clauses can be used wherever an expression is valid. Each *condition* is an expression that returns a `boolean` result. If the condition's result is true, the value of the `CASE` expression is the *result* that follows the condition, and the remainder of the `CASE` expression is not processed. If the condition's result is not true, any subsequent `WHEN` clauses are examined in the same manner. If no `WHEN` *condition* yields true, the value of the `CASE` expression is the *result* of the `ELSE` clause. If the `ELSE` clause is omitted and no condition is true, the result is null.

An example:

```
SELECT * FROM test;

 a
---
 1
 2
 3


SELECT a,
       CASE WHEN a=1 THEN 'one'
            WHEN a=2 THEN 'two'
            ELSE 'other'
       END
    FROM test;

 a | case
---+-------
```

```
 1 | one
 2 | two
 3 | other
```

The data types of all the *result* expressions must be convertible to a single output type. See Section 10.5 for more details.

There is a "simple" form of CASE expression that is a variant of the general form above:

```
CASE expression
    WHEN value THEN result
    [WHEN ...]
    [ELSE result]
END
```

The first *expression* is computed, then compared to each of the *value* expressions in the WHEN clauses until one is found that is equal to it. If no match is found, the *result* of the ELSE clause (or a null value) is returned. This is similar to the switch statement in C.

The example above can be written using the simple CASE syntax:

```
SELECT a,
       CASE a WHEN 1 THEN 'one'
              WHEN 2 THEN 'two'
              ELSE 'other'
       END
    FROM test;

 a | case
---+-------
 1 | one
 2 | two
 3 | other
```

A CASE expression does not evaluate any subexpressions that are not needed to determine the result. For example, this is a possible way of avoiding a division-by-zero failure:

```
SELECT ... WHERE CASE WHEN x <> 0 THEN y/x > 1.5 ELSE false END;
```

> **Note:** As described in Section 4.2.14, there are various situations in which subexpressions of an expression are evaluated at different times, so that the principle that "CASE evaluates only necessary subexpressions" is not ironclad. For example a constant 1/0 subexpression will usually result in a division-by-zero failure at planning time, even if it's within a CASE arm that would never be entered at run time.

9.17.2. COALESCE

```
COALESCE(value [, ...])
```

The COALESCE function returns the first of its arguments that is not null. Null is returned only if all arguments are null. It is often used to substitute a default value for null values when data is retrieved for display, for example:

```
SELECT COALESCE(description, short_description, '(none)') ...
```

This returns description if it is not null, otherwise short_description if it is not null, otherwise (none).

Like a CASE expression, COALESCE only evaluates the arguments that are needed to determine the result; that is, arguments to the right of the first non-null argument are not evaluated. This SQL-standard function provides capabilities similar to NVL and IFNULL, which are used in some other database systems.

9.17.3. NULLIF

```
NULLIF(value1, value2)
```

The NULLIF function returns a null value if *value1* equals *value2*; otherwise it returns *value1*. This can be used to perform the inverse operation of the COALESCE example given above:

```
SELECT NULLIF(value, '(none)') ...
```

In this example, if value is (none), null is returned, otherwise the value of value is returned.

9.17.4. GREATEST and LEAST

```
GREATEST(value [, ...])
```

```
LEAST(value [, ...])
```

The GREATEST and LEAST functions select the largest or smallest value from a list of any number of expressions. The expressions must all be convertible to a common data type, which will be the type of the result (see Section 10.5 for details). NULL values in the list are ignored. The result will be NULL only if all the expressions evaluate to NULL.

Note that GREATEST and LEAST are not in the SQL standard, but are a common extension. Some other databases make them return NULL if any argument is NULL, rather than only when all are NULL.

9.18. Array Functions and Operators

Table 9-45 shows the operators available for array types.

Table 9-45. Array Operators

Operator	Description	Example	Result
=	equal	ARRAY[1.1,2.1,3.1]::int[] = ARRAY[1,2,3]	t

Operator	Description	Example	Result
<>	not equal	ARRAY[1,2,3] <> ARRAY[1,2,4]	t
<	less than	ARRAY[1,2,3] < ARRAY[1,2,4]	t
>	greater than	ARRAY[1,4,3] > ARRAY[1,2,4]	t
<=	less than or equal	ARRAY[1,2,3] <= ARRAY[1,2,3]	t
>=	greater than or equal	ARRAY[1,4,3] >= ARRAY[1,4,3]	t
@>	contains	ARRAY[1,4,3] @> ARRAY[3,1]	t
<@	is contained by	ARRAY[2,7] <@ ARRAY[1,7,4,2,6]	t
&&	overlap (have elements in common)	ARRAY[1,4,3] && ARRAY[2,1]	t
||	array-to-array concatenation	ARRAY[1,2,3] || ARRAY[4,5,6]	{1,2,3,4,5,6}
||	array-to-array concatenation	ARRAY[1,2,3] || ARRAY[[4,5,6],[7,8,9]]	{{1,2,3},{4,5,6},{7,8,9}}
||	element-to-array concatenation	3 || ARRAY[4,5,6]	{3,4,5,6}
||	array-to-element concatenation	ARRAY[4,5,6] || 7	{4,5,6,7}

Array comparisons compare the array contents element-by-element, using the default B-tree comparison function for the element data type. In multidimensional arrays the elements are visited in row-major order (last subscript varies most rapidly). If the contents of two arrays are equal but the dimensionality is different, the first difference in the dimensionality information determines the sort order. (This is a change from versions of PostgreSQL prior to 8.2: older versions would claim that two arrays with the same contents were equal, even if the number of dimensions or subscript ranges were different.)

See Section 8.15 for more details about array operator behavior. See Section 11.2 for more details about which operators support indexed operations.

Table 9-46 shows the functions available for use with array types. See Section 8.15 for more information and examples of the use of these functions.

Table 9-46. Array Functions

Function	Return Type	Description	Example	Result
array_append(anyarray, anyelement)	anyarray	append an element to the end of an array	array_append(ARRAY[1,2], 3)	{1,2,3}
array_cat(anyarray, anyarray)	anyarray	concatenate two arrays	array_cat(ARRAY[1,2,3], ARRAY[4,5])	{1,2,3,4,5}

Function	Return Type	Description	Example	Result
`array_ndims(anyarray)`	`int`	returns the number of dimensions of the array	`array_ndims(ARRAY[[1,2,3], [4,5,6]])`	`2`
`array_dims(anyarray)`	`text`	returns a text representation of array's dimensions	`array_dims(ARRAY[[1,2,3], [4,5,6]])`	`[1:2][1:3]`
`array_fill(anyelement, int[], [, int[]])`	`anyarray`	returns an array initialized with supplied value and dimensions, optionally with lower bounds other than 1	`array_fill(7, ARRAY[3], ARRAY[2])`	`[2:4]={7,7,7}`
`array_length(anyarray, int)`	`int`	returns the length of the requested array dimension	`array_length(array[1,2,3], 1)`	`3`
`array_lower(anyarray, int)`	`int`	returns lower bound of the requested array dimension	`array_lower('[0:2]={1,2,3}'::int[], 1)`	`0`
`array_prepend(anyelement, anyarray)`	`anyarray`	append an element to the beginning of an array	`array_prepend(1, ARRAY[2,3])`	`{1,2,3}`
`array_remove(anyarray, anyelement)`	`anyarray`	remove all elements equal to the given value from the array (array must be one-dimensional)	`array_remove(ARRAY[1,2,3,2], 2)`	`{1,3}`
`array_replace(anyarray, anyelement, anyelement)`	`anyarray`	replace each array element equal to the given value with a new value	`array_replace(ARRAY[3,2,5,4], 5, 3)`	`{3,2,3,4}`
`array_to_string(anyarray, text [, text])`	`text`	concatenates array elements using supplied delimiter and optional null string	`array_to_string(ARRAY[1, 2, 3, NULL, 5], ',', '*')`	`1,2,3,*,5`
`array_upper(anyarray, int)`	`int`	returns upper bound of the requested array dimension	`array_upper(ARRAY[1,8,3,7], 1)`	`4`

Function	Return Type	Description	Example	Result
cardinality(anyarray)	int	returns the total number of elements in the array, or 0 if the array is empty	cardinality(ARRAY[[1,2],[3,4]])	4
string_to_array(text, text [, text])	text[]	splits string into array elements using supplied delimiter and optional null string	string_to_array('xx~^~yy~^~zz', '~^~', 'yy')	{xx,NULL,zz}
unnest(anyarray)	setof anyelement	expand an array to a set of rows	unnest(ARRAY[1,2])	1 2 (2 rows)
unnest(anyarray, anyarray [, ...])	setof anyelement, anyelement [, ...]	expand multiple arrays (possibly of different types) to a set of rows. This is only allowed in the FROM clause; see Section 7.2.1.4	unnest(ARRAY[1,2],ARRAY['foo','bar','baz'])	1 foo 2 bar NULL baz (3 rows)

In string_to_array, if the delimiter parameter is NULL, each character in the input string will become a separate element in the resulting array. If the delimiter is an empty string, then the entire input string is returned as a one-element array. Otherwise the input string is split at each occurrence of the delimiter string.

In string_to_array, if the null-string parameter is omitted or NULL, none of the substrings of the input will be replaced by NULL. In array_to_string, if the null-string parameter is omitted or NULL, any null elements in the array are simply skipped and not represented in the output string.

> **Note:** There are two differences in the behavior of string_to_array from pre-9.1 versions of PostgreSQL. First, it will return an empty (zero-element) array rather than NULL when the input string is of zero length. Second, if the delimiter string is NULL, the function splits the input into individual characters, rather than returning NULL as before.

See also Section 9.20 about the aggregate function array_agg for use with arrays.

9.19. Range Functions and Operators

See Section 8.17 for an overview of range types.

Table 9-47 shows the operators available for range types.

Table 9-47. Range Operators

Operator	Description	Example	Result

Operator	Description	Example	Result
=	equal	int4range(1,5) = '[1,4]'::int4range	t
<>	not equal	numrange(1.1,2.2) <> numrange(1.1,2.3)	t
<	less than	int4range(1,10) < int4range(2,3)	t
>	greater than	int4range(1,10) > int4range(1,5)	t
<=	less than or equal	numrange(1.1,2.2) <= numrange(1.1,2.2)	t
>=	greater than or equal	numrange(1.1,2.2) >= numrange(1.1,2.0)	t
@>	contains range	int4range(2,4) @> int4range(2,3)	t
@>	contains element	'[2011-01-01,2011-03-01)'::tsrange @> '2011-01-10'::timestamp	t
<@	range is contained by	int4range(2,4) <@ int4range(1,7)	t
<@	element is contained by	42 <@ int4range(1,7)	f
&&	overlap (have points in common)	int8range(3,7) && int8range(4,12)	t
<<	strictly left of	int8range(1,10) << int8range(100,110)	t
>>	strictly right of	int8range(50,60) >> int8range(20,30)	t
&<	does not extend to the right of	int8range(1,20) &< int8range(18,20)	t
&>	does not extend to the left of	int8range(7,20) &> int8range(5,10)	t
-|-	is adjacent to	numrange(1.1,2.2) -|- numrange(2.2,3.3)	t
+	union	numrange(5,15) + numrange(10,20)	[5,20)

Operator	Description	Example	Result
*	intersection	int8range(5,15) * int8range(10,20)	[10,15)
-	difference	int8range(5,15) - int8range(10,20)	[5,10)

The simple comparison operators <, >, <=, and >= compare the lower bounds first, and only if those are equal, compare the upper bounds. These comparisons are not usually very useful for ranges, but are provided to allow B-tree indexes to be constructed on ranges.

The left-of/right-of/adjacent operators always return false when an empty range is involved; that is, an empty range is not considered to be either before or after any other range.

The union and difference operators will fail if the resulting range would need to contain two disjoint sub-ranges, as such a range cannot be represented.

Table 9-48 shows the functions available for use with range types.

Table 9-48. Range Functions

Function	Return Type	Description	Example	Result
lower(anyrange)	range's element type	lower bound of range	lower(numrange(1.1,2.2))	1.1
upper(anyrange)	range's element type	upper bound of range	upper(numrange(1.1,2.2))	2.2
isempty(anyrange)	boolean	is the range empty?	isempty(numrange(1.1,2.2))	false
lower_inc(anyrange)	boolean	is the lower bound inclusive?	lower_inc(numrange(1.1,2.2))	true
upper_inc(anyrange)	boolean	is the upper bound inclusive?	upper_inc(numrange(1.1,2.2))	false
lower_inf(anyrange)	boolean	is the lower bound infinite?	lower_inf('(,)'::daterange)	true
upper_inf(anyrange)	boolean	is the upper bound infinite?	upper_inf('(,)'::daterange)	true

The lower and upper functions return null if the range is empty or the requested bound is infinite. The lower_inc, upper_inc, lower_inf, and upper_inf functions all return false for an empty range.

9.20. Aggregate Functions

Aggregate functions compute a single result from a set of input values. The built-in normal aggregate

functions are listed in Table 9-49 and Table 9-50. The built-in ordered-set aggregate functions are listed in Table 9-51 and Table 9-52. The special syntax considerations for aggregate functions are explained in Section 4.2.7. Consult Section 2.7 for additional introductory information.

Table 9-49. General-Purpose Aggregate Functions

Function	Argument Type(s)	Return Type	Description
`array_agg(`*`expression`*`)`	any	array of the argument type	input values, including nulls, concatenated into an array
`avg(`*`expression`*`)`	`smallint`, `int`, `bigint`, `real`, `double precision`, `numeric`, or `interval`	`numeric` for any integer-type argument, `double precision` for a floating-point argument, otherwise the same as the argument data type	the average (arithmetic mean) of all input values
`bit_and(`*`expression`*`)`	`smallint`, `int`, `bigint`, or `bit`	same as argument data type	the bitwise AND of all non-null input values, or null if none
`bit_or(`*`expression`*`)`	`smallint`, `int`, `bigint`, or `bit`	same as argument data type	the bitwise OR of all non-null input values, or null if none
`bool_and(`*`expression`*`)`	`bool`	`bool`	true if all input values are true, otherwise false
`bool_or(`*`expression`*`)`	`bool`	`bool`	true if at least one input value is true, otherwise false
`count(*)`		`bigint`	number of input rows
`count(`*`expression`*`)`	any	`bigint`	number of input rows for which the value of *`expression`* is not null
`every(`*`expression`*`)`	`bool`	`bool`	equivalent to `bool_and`
`json_agg(`*`expression`*`)`	any	`json`	aggregates values as a JSON array
`json_object_agg(`*`name`*`, `*`value`*`)`	`(any, any)`	`json`	aggregates name/value pairs as a JSON object
`max(`*`expression`*`)`	any array, numeric, string, or date/time type	same as argument type	maximum value of *`expression`* across all input values
`min(`*`expression`*`)`	any array, numeric, string, or date/time type	same as argument type	minimum value of *`expression`* across all input values

Function	Argument Type(s)	Return Type	Description
string_agg(*expression*, *delimiter*)	(text, text) or (bytea, bytea)	same as argument types	input values concatenated into a string, separated by delimiter
sum(*expression*)	smallint, int, bigint, real, double precision, numeric, interval, or money	bigint for smallint or int arguments, numeric for bigint arguments, otherwise the same as the argument data type	sum of *expression* across all input values
xmlagg(*expression*)	xml	xml	concatenation of XML values (see also Section 9.14.1.7)

It should be noted that except for count, these functions return a null value when no rows are selected. In particular, sum of no rows returns null, not zero as one might expect, and array_agg returns null rather than an empty array when there are no input rows. The coalesce function can be used to substitute zero or an empty array for null when necessary.

Note: Boolean aggregates bool_and and bool_or correspond to standard SQL aggregates every and any or some. As for any and some, it seems that there is an ambiguity built into the standard syntax:

```
SELECT b1 = ANY((SELECT b2 FROM t2 ...)) FROM t1 ...;
```

Here ANY can be considered either as introducing a subquery, or as being an aggregate function, if the subquery returns one row with a Boolean value. Thus the standard name cannot be given to these aggregates.

Note: Users accustomed to working with other SQL database management systems might be disappointed by the performance of the count aggregate when it is applied to the entire table. A query like:

```
SELECT count(*) FROM sometable;
```

will require effort proportional to the size of the table: PostgreSQL will need to scan either the entire table or the entirety of an index which includes all rows in the table.

The aggregate functions array_agg, json_agg, json_object_agg, string_agg, and xmlagg, as well as similar user-defined aggregate functions, produce meaningfully different result values depending on the order of the input values. This ordering is unspecified by default, but can be controlled by writing an ORDER BY clause within the aggregate call, as shown in Section 4.2.7. Alternatively, supplying the input values from a sorted subquery will usually work. For example:

```
SELECT xmlagg(x) FROM (SELECT x FROM test ORDER BY y DESC) AS tab;
```

But this syntax is not allowed in the SQL standard, and is not portable to other database systems.

Table 9-50 shows aggregate functions typically used in statistical analysis. (These are separated out merely to avoid cluttering the listing of more-commonly-used aggregates.) Where the description

mentions *N*, it means the number of input rows for which all the input expressions are non-null. In all cases, null is returned if the computation is meaningless, for example when *N* is zero.

Table 9-50. Aggregate Functions for Statistics

Function	Argument Type	Return Type	Description
corr(*Y*, *X*)	double precision	double precision	correlation coefficient
covar_pop(*Y*, *X*)	double precision	double precision	population covariance
covar_samp(*Y*, *X*)	double precision	double precision	sample covariance
regr_avgx(*Y*, *X*)	double precision	double precision	average of the independent variable (sum(*X*)/*N*)
regr_avgy(*Y*, *X*)	double precision	double precision	average of the dependent variable (sum(*Y*)/*N*)
regr_count(*Y*, *X*)	double precision	bigint	number of input rows in which both expressions are nonnull
regr_intercept(*Y*, *X*)	double precision	double precision	y-intercept of the least-squares-fit linear equation determined by the (*X*, *Y*) pairs
regr_r2(*Y*, *X*)	double precision	double precision	square of the correlation coefficient
regr_slope(*Y*, *X*)	double precision	double precision	slope of the least-squares-fit linear equation determined by the (*X*, *Y*) pairs
regr_sxx(*Y*, *X*)	double precision	double precision	sum(*X*^2) - sum(*X*)^2/*N* ("sum of squares" of the independent variable)
regr_sxy(*Y*, *X*)	double precision	double precision	sum(*X***Y*) - sum(*X*) * sum(*Y*)/*N* ("sum of products" of independent times dependent variable)
regr_syy(*Y*, *X*)	double precision	double precision	sum(*Y*^2) - sum(*Y*)^2/*N* ("sum of squares" of the dependent variable)
stddev(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	historical alias for stddev_samp

Function	Argument Type	Return Type	Description
stddev_pop(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	population standard deviation of the input values
stddev_samp(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	sample standard deviation of the input values
variance(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	historical alias for var_samp
var_pop(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	population variance of the input values (square of the population standard deviation)
var_samp(*expression*)	smallint, int, bigint, real, double precision, or numeric	double precision for floating-point arguments, otherwise numeric	sample variance of the input values (square of the sample standard deviation)

Table 9-51 shows some aggregate functions that use the *ordered-set aggregate* syntax. These functions are sometimes referred to as "inverse distribution" functions.

Table 9-51. Ordered-Set Aggregate Functions

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Description
mode() WITHIN GROUP (ORDER BY *sort_expression*)		any sortable type	same as sort expression	returns the most frequent input value (arbitrarily choosing the first one if there are multiple equally-frequent results)
percentile_cont(*fraction*) WITHIN GROUP (ORDER BY *sort_expression*)	double precision	double precision or interval	same as sort expression	continuous percentile: returns a value corresponding to the specified fraction in the ordering, interpolating between adjacent input items if needed

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Description
`percentile_cont(`*fractions*`) WITHIN GROUP (ORDER BY` *sort_expression*`)`	`double precision[]`	`double precision` or `interval`	array of sort expression's type	multiple continuous percentile: returns an array of results matching the shape of the `fractions` parameter, with each non-null element replaced by the value corresponding to that percentile
`percentile_disc(`*fraction*`) WITHIN GROUP (ORDER BY` *sort_expression*`)`	`double precision`	any sortable type	same as sort expression	discrete percentile: returns the first input value whose position in the ordering equals or exceeds the specified fraction
`percentile_disc(`*fractions*`) WITHIN GROUP (ORDER BY` *sort_expression*`)`	`double precision[]`	any sortable type	array of sort expression's type	multiple discrete percentile: returns an array of results matching the shape of the `fractions` parameter, with each non-null element replaced by the input value corresponding to that percentile

All the aggregates listed in Table 9-51 ignore null values in their sorted input. For those that take a *`fraction`* parameter, the fraction value must be between 0 and 1; an error is thrown if not. However, a null fraction value simply produces a null result.

Each of the aggregates listed in Table 9-52 is associated with a window function of the same name defined in Section 9.21. In each case, the aggregate result is the value that the associated window function would have returned for the "hypothetical" row constructed from *`args`*, if such a row had been added to the sorted group of rows computed from the *`sorted_args`*.

Table 9-52. Hypothetical-Set Aggregate Functions

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Description

Function	Direct Argument Type(s)	Aggregated Argument Type(s)	Return Type	Description
rank(*args*) WITHIN GROUP (ORDER BY *sorted_args*)	VARIADIC "any"	VARIADIC "any"	bigint	rank of the hypothetical row, with gaps for duplicate rows
dense_rank(*args*) WITHIN GROUP (ORDER BY *sorted_args*)	VARIADIC "any"	VARIADIC "any"	bigint	rank of the hypothetical row, without gaps
percent_rank(*args*) WITHIN GROUP (ORDER BY *sorted_args*)	VARIADIC "any"	VARIADIC "any"	double precision	relative rank of the hypothetical row, ranging from 0 to 1
cume_dist(*args*) WITHIN GROUP (ORDER BY *sorted_args*)	VARIADIC "any"	VARIADIC "any"	double precision	relative rank of the hypothetical row, ranging from 1/*N* to 1

For each of these hypothetical-set aggregates, the list of direct arguments given in *args* must match the number and types of the aggregated arguments given in *sorted_args*. Unlike most built-in aggregates, these aggregates are not strict, that is they do not drop input rows containing nulls. Null values sort according to the rule specified in the ORDER BY clause.

9.21. Window Functions

Window functions provide the ability to perform calculations across sets of rows that are related to the current query row. See Section 3.5 for an introduction to this feature, and Section 4.2.8 for syntax details.

The built-in window functions are listed in Table 9-53. Note that these functions *must* be invoked using window function syntax; that is an OVER clause is required.

In addition to these functions, any built-in or user-defined normal aggregate function (but not ordered-set or hypothetical-set aggregates) can be used as a window function; see Section 9.20 for a list of the built-in aggregates. Aggregate functions act as window functions only when an OVER clause follows the call; otherwise they act as regular aggregates.

Table 9-53. General-Purpose Window Functions

Function	Return Type	Description
row_number()	bigint	number of the current row within its partition, counting from 1

Function	Return Type	Description
rank()	bigint	rank of the current row with gaps; same as row_number of its first peer
dense_rank()	bigint	rank of the current row without gaps; this function counts peer groups
percent_rank()	double precision	relative rank of the current row: (rank - 1) / (total rows - 1)
cume_dist()	double precision	relative rank of the current row: (number of rows preceding or peer with current row) / (total rows)
ntile(*num_buckets* integer)	integer	integer ranging from 1 to the argument value, dividing the partition as equally as possible
lag(*value* any [, *offset* integer [, *default* any]])	same type as *value*	returns *value* evaluated at the row that is *offset* rows before the current row within the partition; if there is no such row, instead return *default*. Both *offset* and *default* are evaluated with respect to the current row. If omitted, *offset* defaults to 1 and *default* to null
lead(*value* any [, *offset* integer [, *default* any]])	same type as *value*	returns *value* evaluated at the row that is *offset* rows after the current row within the partition; if there is no such row, instead return *default*. Both *offset* and *default* are evaluated with respect to the current row. If omitted, *offset* defaults to 1 and *default* to null
first_value(*value* any)	same type as *value*	returns *value* evaluated at the row that is the first row of the window frame
last_value(*value* any)	same type as *value*	returns *value* evaluated at the row that is the last row of the window frame
nth_value(*value* any, *nth* integer)	same type as *value*	returns *value* evaluated at the row that is the *nth* row of the window frame (counting from 1); null if no such row

All of the functions listed in Table 9-53 depend on the sort ordering specified by the ORDER BY clause of the associated window definition. Rows that are not distinct in the ORDER BY ordering are said to be *peers*; the four ranking functions are defined so that they give the same answer for any two peer

rows.

Note that first_value, last_value, and nth_value consider only the rows within the "window frame", which by default contains the rows from the start of the partition through the last peer of the current row. This is likely to give unhelpful results for last_value and sometimes also nth_value. You can redefine the frame by adding a suitable frame specification (RANGE or ROWS) to the OVER clause. See Section 4.2.8 for more information about frame specifications.

When an aggregate function is used as a window function, it aggregates over the rows within the current row's window frame. An aggregate used with ORDER BY and the default window frame definition produces a "running sum" type of behavior, which may or may not be what's wanted. To obtain aggregation over the whole partition, omit ORDER BY or use ROWS BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING. Other frame specifications can be used to obtain other effects.

> **Note:** The SQL standard defines a RESPECT NULLS or IGNORE NULLS option for lead, lag, first_value, last_value, and nth_value. This is not implemented in PostgreSQL: the behavior is always the same as the standard's default, namely RESPECT NULLS. Likewise, the standard's FROM FIRST or FROM LAST option for nth_value is not implemented: only the default FROM FIRST behavior is supported. (You can achieve the result of FROM LAST by reversing the ORDER BY ordering.)

9.22. Subquery Expressions

This section describes the SQL-compliant subquery expressions available in PostgreSQL. All of the expression forms documented in this section return Boolean (true/false) results.

9.22.1. EXISTS

```
EXISTS (subquery)
```

The argument of EXISTS is an arbitrary SELECT statement, or *subquery*. The subquery is evaluated to determine whether it returns any rows. If it returns at least one row, the result of EXISTS is "true"; if the subquery returns no rows, the result of EXISTS is "false".

The subquery can refer to variables from the surrounding query, which will act as constants during any one evaluation of the subquery.

The subquery will generally only be executed long enough to determine whether at least one row is returned, not all the way to completion. It is unwise to write a subquery that has side effects (such as calling sequence functions); whether the side effects occur might be unpredictable.

Since the result depends only on whether any rows are returned, and not on the contents of those rows, the output list of the subquery is normally unimportant. A common coding convention is to write all EXISTS tests in the form EXISTS(SELECT 1 WHERE ...). There are exceptions to this rule however, such as subqueries that use INTERSECT.

This simple example is like an inner join on col2, but it produces at most one output row for each tab1 row, even if there are several matching tab2 rows:

```
SELECT col1
FROM tab1
WHERE EXISTS (SELECT 1 FROM tab2 WHERE col2 = tab1.col2);
```

9.22.2. IN

```
expression IN (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of IN is "true" if any equal subquery row is found. The result is "false" if no equal row is found (including the case where the subquery returns no rows).

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the IN construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor IN (subquery)
```

The left-hand side of this form of IN is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of IN is "true" if any equal subquery row is found. The result is "false" if no equal row is found (including the case where the subquery returns no rows).

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of IN is null.

9.22.3. NOT IN

```
expression NOT IN (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result. The result of NOT IN is "true" if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is "false" if any equal row is found.

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand row yields null, the result of the NOT IN construct will be null, not true. This is in accordance with SQL's normal rules for Boolean combinations of null values.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor NOT IN (subquery)
```

The left-hand side of this form of NOT IN is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result. The result of NOT IN is "true" if only unequal subquery rows are found (including the case where the subquery returns no rows). The result is "false" if any equal row is found.

As usual, null values in the rows are combined per the normal rules of SQL Boolean expressions. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of that row comparison is unknown (null). If all the per-row results are either unequal or null, with at least one null, then the result of NOT IN is null.

9.22.4. ANY/SOME

```
expression operator ANY (subquery)
expression operator SOME (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of ANY is "true" if any true result is obtained. The result is "false" if no true result is found (including the case where the subquery returns no rows).

SOME is a synonym for ANY. IN is equivalent to = ANY.

Note that if there are no successes and at least one right-hand row yields null for the operator's result, the result of the ANY construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ANY (subquery)
row_constructor operator SOME (subquery)
```

The left-hand side of this form of ANY is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result, using the given *operator*. The result of ANY is "true" if the comparison returns true for any subquery row. The result is "false" if the comparison returns false for every subquery row (including the case where the subquery returns no rows). The result is NULL if the comparison does not return true for any row, and it returns NULL for at least one row.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.22.5. ALL

```
expression operator ALL (subquery)
```

The right-hand side is a parenthesized subquery, which must return exactly one column. The left-hand expression is evaluated and compared to each row of the subquery result using the given *operator*, which must yield a Boolean result. The result of ALL is "true" if all rows yield true (including the case where the subquery returns no rows). The result is "false" if any false result is found. The result is NULL if the comparison does not return false for any row, and it returns NULL for at least one row.

NOT IN is equivalent to <> ALL.

As with EXISTS, it's unwise to assume that the subquery will be evaluated completely.

```
row_constructor operator ALL (subquery)
```

The left-hand side of this form of ALL is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there

are expressions in the left-hand row. The left-hand expressions are evaluated and compared row-wise to each row of the subquery result, using the given *operator*. The result of ALL is "true" if the comparison returns true for all subquery rows (including the case where the subquery returns no rows). The result is "false" if the comparison returns false for any subquery row. The result is NULL if the comparison does not return false for any subquery row, and it returns NULL for at least one row.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.22.6. Single-row Comparison

```
row_constructor operator (subquery)
```

The left-hand side is a row constructor, as described in Section 4.2.13. The right-hand side is a parenthesized subquery, which must return exactly as many columns as there are expressions in the left-hand row. Furthermore, the subquery cannot return more than one row. (If it returns zero rows, the result is taken to be null.) The left-hand side is evaluated and compared row-wise to the single subquery result row.

See Section 9.23.5 for details about the meaning of a row constructor comparison.

9.23. Row and Array Comparisons

This section describes several specialized constructs for making multiple comparisons between groups of values. These forms are syntactically related to the subquery forms of the previous section, but do not involve subqueries. The forms involving array subexpressions are PostgreSQL extensions; the rest are SQL-compliant. All of the expression forms documented in this section return Boolean (true/false) results.

9.23.1. IN

```
expression IN (value [, ...])
```

The right-hand side is a parenthesized list of scalar expressions. The result is "true" if the left-hand expression's result is equal to any of the right-hand expressions. This is a shorthand notation for

```
expression = value1
OR
expression = value2
OR
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the IN construct will be null, not false. This is in accordance with SQL's normal rules for Boolean combinations of null values.

9.23.2. NOT IN

```
expression NOT IN (value [, ...])
```

The right-hand side is a parenthesized list of scalar expressions. The result is "true" if the left-hand expression's result is unequal to all of the right-hand expressions. This is a shorthand notation for

```
expression <> value1
AND
expression <> value2
AND
...
```

Note that if the left-hand expression yields null, or if there are no equal right-hand values and at least one right-hand expression yields null, the result of the `NOT IN` construct will be null, not true as one might naively expect. This is in accordance with SQL's normal rules for Boolean combinations of null values.

> **Tip:** `x NOT IN y` is equivalent to `NOT (x IN y)` in all cases. However, null values are much more likely to trip up the novice when working with `NOT IN` than when working with `IN`. It is best to express your condition positively if possible.

9.23.3. ANY/SOME (array)

```
expression operator ANY (array expression)
expression operator SOME (array expression)
```

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of `ANY` is "true" if any true result is obtained. The result is "false" if no true result is found (including the case where the array has zero elements).

If the array expression yields a null array, the result of `ANY` will be null. If the left-hand expression yields null, the result of `ANY` is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no true comparison result is obtained, the result of `ANY` will be null, not false (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

`SOME` is a synonym for `ANY`.

9.23.4. ALL (array)

```
expression operator ALL (array expression)
```

The right-hand side is a parenthesized expression, which must yield an array value. The left-hand expression is evaluated and compared to each element of the array using the given *operator*, which must yield a Boolean result. The result of `ALL` is "true" if all comparisons yield true (including the case where the array has zero elements). The result is "false" if any false result is found.

If the array expression yields a null array, the result of `ALL` will be null. If the left-hand expression yields null, the result of `ALL` is ordinarily null (though a non-strict comparison operator could possibly yield a different result). Also, if the right-hand array contains any null elements and no false comparison result is obtained, the result of `ALL` will be null, not true (again, assuming a strict comparison operator). This is in accordance with SQL's normal rules for Boolean combinations of null values.

9.23.5. Row Constructor Comparison

row_constructor operator row_constructor

Each side is a row constructor, as described in Section 4.2.13. The two row values must have the same number of fields. Each side is evaluated and they are compared row-wise. Row constructor comparisons are allowed when the *operator* is =, <>, <, <=, > or >=. Every row element must be of a type which has a default B-tree operator class or the attempted comparison may generate an error.

> **Note:** Errors related to the number or types of elements might not occur if the comparison is resolved using earlier columns.

The = and <> cases work slightly differently from the others. Two rows are considered equal if all their corresponding members are non-null and equal; the rows are unequal if any corresponding members are non-null and unequal; otherwise the result of the row comparison is unknown (null).

For the <, <=, > and >= cases, the row elements are compared left-to-right, stopping as soon as an unequal or null pair of elements is found. If either of this pair of elements is null, the result of the row comparison is unknown (null); otherwise comparison of this pair of elements determines the result. For example, `ROW(1,2,NULL) < ROW(1,3,0)` yields true, not null, because the third pair of elements are not considered.

> **Note:** Prior to PostgreSQL 8.2, the <, <=, > and >= cases were not handled per SQL specification. A comparison like `ROW(a,b) < ROW(c,d)` was implemented as `a < c AND b < d` whereas the correct behavior is equivalent to `a < c OR (a = c AND b < d)`.

row_constructor IS DISTINCT FROM *row_constructor*

This construct is similar to a <> row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will either be true or false, never null.

row_constructor IS NOT DISTINCT FROM *row_constructor*

This construct is similar to a = row comparison, but it does not yield null for null inputs. Instead, any null value is considered unequal to (distinct from) any non-null value, and any two nulls are considered equal (not distinct). Thus the result will always be either true or false, never null.

9.23.6. Composite Type Comparison

record operator record

The SQL specification requires row-wise comparison to return NULL if the result depends on comparing two NULL values or a NULL and a non-NULL. PostgreSQL does this only when comparing the results of two row constructors (as in Section 9.23.5) or comparing a row constructor to the output of a subquery (as in Section 9.22). In other contexts where two composite-type values are compared, two NULL field values are considered equal, and a NULL is considered larger than a non-NULL. This is necessary in order to have consistent sorting and indexing behavior for composite types.

Each side is evaluated and they are compared row-wise. Composite type comparisons are allowed when the *operator* is =, <>, <, <=, > or >=, or has semantics similar to one of these. (To be specific, an operator can be a row comparison operator if it is a member of a B-tree operator class, or is the negator of the = member of a B-tree operator class.) The default behavior of the above operators is the same as for `IS [ NOT ] DISTINCT FROM` for row constructors (see Section 9.23.5).

To support matching of rows which include elements without a default B-tree operator class, the following operators are defined for composite type comparison: *=, *<>, *<, *<=, *>, and *>=. These operators compare the internal binary representation of the two rows. Two rows might have a different binary representation even though comparisons of the two rows with the equality operator is true. The ordering of rows under these comparison operators is deterministic but not otherwise meaningful. These operators are used internally for materialized views and might be useful for other specialized purposes such as replication but are not intended to be generally useful for writing queries.

9.24. Set Returning Functions

This section describes functions that possibly return more than one row. The most widely used functions in this class are series generating functions, as detailed in Table 9-54 and Table 9-55. Other, more specialized set-returning functions are described elsewhere in this manual. See Section 7.2.1.4 for ways to combine multiple set-returning functions.

Table 9-54. Series Generating Functions

Function	Argument Type	Return Type	Description
`generate_series(start, stop)`	`int` or `bigint`	`setof int` or `setof bigint` (same as argument type)	Generate a series of values, from `start` to `stop` with a step size of one
`generate_series(start, stop, step)`	`int` or `bigint`	`setof int` or `setof bigint` (same as argument type)	Generate a series of values, from `start` to `stop` with a step size of `step`
`generate_series(start, stop, step interval)`	`timestamp` or `timestamp with time zone`	`setof timestamp` or `setof timestamp with time zone` (same as argument type)	Generate a series of values, from `start` to `stop` with a step size of `step`

When `step` is positive, zero rows are returned if `start` is greater than `stop`. Conversely, when `step` is negative, zero rows are returned if `start` is less than `stop`. Zero rows are also returned for `NULL` inputs. It is an error for `step` to be zero. Some examples follow:

```
SELECT * FROM generate_series(2,4);
 generate_series
-----------------
               2
               3
               4
(3 rows)

SELECT * FROM generate_series(5,1,-2);
```

```
 generate_series
-----------------
               5
               3
               1
(3 rows)

SELECT * FROM generate_series(4,3);
 generate_series
-----------------
(0 rows)

-- this example relies on the date-plus-integer operator
SELECT current_date + s.a AS dates FROM generate_series(0,14,7) AS s(a);
   dates
------------
 2004-02-05
 2004-02-12
 2004-02-19
(3 rows)

SELECT * FROM generate_series('2008-03-01 00:00'::timestamp,
                              '2008-03-04 12:00', '10 hours');
   generate_series
---------------------
 2008-03-01 00:00:00
 2008-03-01 10:00:00
 2008-03-01 20:00:00
 2008-03-02 06:00:00
 2008-03-02 16:00:00
 2008-03-03 02:00:00
 2008-03-03 12:00:00
 2008-03-03 22:00:00
 2008-03-04 08:00:00
(9 rows)
```

Table 9-55. Subscript Generating Functions

Function	Return Type	Description
`generate_subscripts(array anyarray, dim int)`	`setof int`	Generate a series comprising the given array's subscripts.
`generate_subscripts(array anyarray, dim int, reverse boolean)`	`setof int`	Generate a series comprising the given array's subscripts. When `reverse` is true, the series is returned in reverse order.

`generate_subscripts` is a convenience function that generates the set of valid subscripts for the specified dimension of the given array. Zero rows are returned for arrays that do not have the requested dimension, or for NULL arrays (but valid subscripts are returned for NULL array elements). Some examples follow:

```
-- basic usage
```

```
SELECT generate_subscripts('{NULL,1,NULL,2}'::int[], 1) AS s;
 s
---
 1
 2
 3
 4
(4 rows)

-- presenting an array, the subscript and the subscripted
-- value requires a subquery
SELECT * FROM arrays;
         a
--------------------
 {-1,-2}
 {100,200,300}
(2 rows)

SELECT a AS array, s AS subscript, a[s] AS value
FROM (SELECT generate_subscripts(a, 1) AS s, a FROM arrays) foo;
     array     | subscript | value
---------------+-----------+-------
 {-1,-2}       |         1 |    -1
 {-1,-2}       |         2 |    -2
 {100,200,300} |         1 |   100
 {100,200,300} |         2 |   200
 {100,200,300} |         3 |   300
(5 rows)

-- unnest a 2D array
CREATE OR REPLACE FUNCTION unnest2(anyarray)
RETURNS SETOF anyelement AS $$
select $1[i][j]
   from generate_subscripts($1,1) g1(i),
        generate_subscripts($1,2) g2(j);
$$ LANGUAGE sql IMMUTABLE;
CREATE FUNCTION
SELECT * FROM unnest2(ARRAY[[1,2],[3,4]]);
 unnest2
---------
       1
       2
       3
       4
(4 rows)
```

When a function in the `FROM` clause is suffixed by `WITH ORDINALITY`, a `bigint` column is appended to the output which starts from 1 and increments by 1 for each row of the function's output. This is most useful in the case of set returning functions such as `unnest()`.

```
-- set returning function WITH ORDINALITY
SELECT * FROM pg_ls_dir('.') WITH ORDINALITY AS t(ls,n);
       ls        | n
-----------------+----
 pg_serial       |  1
 pg_twophase     |  2
```

```
 postmaster.opts |  3
 pg_notify       |  4
 postgresql.conf |  5
 pg_tblspc       |  6
 logfile         |  7
 base            |  8
 postmaster.pid  |  9
 pg_ident.conf   | 10
 global          | 11
 pg_clog         | 12
 pg_snapshots    | 13
 pg_multixact    | 14
 PG_VERSION      | 15
 pg_xlog         | 16
 pg_hba.conf     | 17
 pg_stat_tmp     | 18
 pg_subtrans     | 19
(19 rows)
```

9.25. System Information Functions

Table 9-56 shows several functions that extract session and system information.

In addition to the functions listed in this section, there are a number of functions related to the statistics system that also provide system information. See Section 27.2.2 for more information.

Table 9-56. Session Information Functions

Name	Return Type	Description
`current_catalog`	`name`	name of current database (called “catalog” in the SQL standard)
`current_database()`	`name`	name of current database
`current_query()`	`text`	text of the currently executing query, as submitted by the client (might contain more than one statement)
`current_schema[()]`	`name`	name of current schema
`current_schemas(boolean)`	`name[]`	names of schemas in search path, optionally including implicit schemas
`current_user`	`name`	user name of current execution context
`inet_client_addr()`	`inet`	address of the remote connection
`inet_client_port()`	`int`	port of the remote connection
`inet_server_addr()`	`inet`	address of the local connection
`inet_server_port()`	`int`	port of the local connection

Name	Return Type	Description
pg_backend_pid()	int	Process ID of the server process attached to the current session
pg_conf_load_time()	timestamp with time zone	configuration load time
pg_is_other_temp_schema(oid)	boolean	is schema another session's temporary schema?
pg_listening_channels()	setof text	channel names that the session is currently listening on
pg_my_temp_schema()	oid	OID of session's temporary schema, or 0 if none
pg_postmaster_start_time()	timestamp with time zone	server start time
pg_trigger_depth()	int	current nesting level of PostgreSQL triggers (0 if not called, directly or indirectly, from inside a trigger)
session_user	name	session user name
user	name	equivalent to current_user
version()	text	PostgreSQL version information

Note: current_catalog, current_schema, current_user, session_user, and user have special syntactic status in SQL: they must be called without trailing parentheses. (In PostgreSQL, parentheses can optionally be used with current_schema, but not with the others.)

The session_user is normally the user who initiated the current database connection; but superusers can change this setting with SET SESSION AUTHORIZATION. The current_user is the user identifier that is applicable for permission checking. Normally it is equal to the session user, but it can be changed with SET ROLE. It also changes during the execution of functions with the attribute SECURITY DEFINER. In Unix parlance, the session user is the "real user" and the current user is the "effective user".

current_schema returns the name of the schema that is first in the search path (or a null value if the search path is empty). This is the schema that will be used for any tables or other named objects that are created without specifying a target schema. current_schemas(boolean) returns an array of the names of all schemas presently in the search path. The Boolean option determines whether or not implicitly included system schemas such as pg_catalog are included in the returned search path.

Note: The search path can be altered at run time. The command is:

```
SET search_path TO schema [, schema, ...]
```

pg_listening_channels returns a set of names of channels that the current session is listening to. See LISTEN for more information.

`inet_client_addr` returns the IP address of the current client, and `inet_client_port` returns the port number. `inet_server_addr` returns the IP address on which the server accepted the current connection, and `inet_server_port` returns the port number. All these functions return NULL if the current connection is via a Unix-domain socket.

`pg_my_temp_schema` returns the OID of the current session's temporary schema, or zero if it has none (because it has not created any temporary tables). `pg_is_other_temp_schema` returns true if the given OID is the OID of another session's temporary schema. (This can be useful, for example, to exclude other sessions' temporary tables from a catalog display.)

`pg_postmaster_start_time` returns the `timestamp with time zone` when the server started.

`pg_conf_load_time` returns the `timestamp with time zone` when the server configuration files were last loaded. (If the current session was alive at the time, this will be the time when the session itself re-read the configuration files, so the reading will vary a little in different sessions. Otherwise it is the time when the postmaster process re-read the configuration files.)

`version` returns a string describing the PostgreSQL server's version.

Table 9-57 lists functions that allow the user to query object access privileges programmatically. See Section 5.6 for more information about privileges.

Table 9-57. Access Privilege Inquiry Functions

Name	Return Type	Description
`has_any_column_privilege(user, table, privilege)`	`boolean`	does user have privilege for any column of table
`has_any_column_privilege(table, privilege)`	`boolean`	does current user have privilege for any column of table
`has_column_privilege(user, table, column, privilege)`	`boolean`	does user have privilege for column
`has_column_privilege(table, column, privilege)`	`boolean`	does current user have privilege for column
`has_database_privilege(user, database, privilege)`	`boolean`	does user have privilege for database
`has_database_privilege(database, privilege)`	`boolean`	does current user have privilege for database
`has_foreign_data_wrapper_privilege(user, fdw, privilege)`	`boolean`	does user have privilege for foreign-data wrapper
`has_foreign_data_wrapper_privilege(fdw, privilege)`	`boolean`	does current user have privilege for foreign-data wrapper
`has_function_privilege(user, function, privilege)`	`boolean`	does user have privilege for function
`has_function_privilege(function, privilege)`	`boolean`	does current user have privilege for function
`has_language_privilege(user, language, privilege)`	`boolean`	does user have privilege for language
`has_language_privilege(language, privilege)`	`boolean`	does current user have privilege for language
`has_schema_privilege(user, schema, privilege)`	`boolean`	does user have privilege for schema

Name	Return Type	Description
has_schema_privilege(schema, privilege)	boolean	does current user have privilege for schema
has_sequence_privilege(user, sequence, privilege)	boolean	does user have privilege for sequence
has_sequence_privilege(sequence, privilege)	boolean	does current user have privilege for sequence
has_server_privilege(user, server, privilege)	boolean	does user have privilege for foreign server
has_server_privilege(server, privilege)	boolean	does current user have privilege for foreign server
has_table_privilege(user, table, privilege)	boolean	does user have privilege for table
has_table_privilege(table, privilege)	boolean	does current user have privilege for table
has_tablespace_privilege(user, tablespace, privilege)	boolean	does user have privilege for tablespace
has_tablespace_privilege(tablespace, privilege)	boolean	does current user have privilege for tablespace
pg_has_role(user, role, privilege)	boolean	does user have privilege for role
pg_has_role(role, privilege)	boolean	does current user have privilege for role

has_table_privilege checks whether a user can access a table in a particular way. The user can be specified by name, by OID (pg_authid.oid), public to indicate the PUBLIC pseudo-role, or if the argument is omitted current_user is assumed. The table can be specified by name or by OID. (Thus, there are actually six variants of has_table_privilege, which can be distinguished by the number and types of their arguments.) When specifying by name, the name can be schema-qualified if necessary. The desired access privilege type is specified by a text string, which must evaluate to one of the values SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER. Optionally, WITH GRANT OPTION can be added to a privilege type to test whether the privilege is held with grant option. Also, multiple privilege types can be listed separated by commas, in which case the result will be true if any of the listed privileges is held. (Case of the privilege string is not significant, and extra whitespace is allowed between but not within privilege names.) Some examples:

```
SELECT has_table_privilege('myschema.mytable', 'select');
SELECT has_table_privilege('joe', 'mytable', 'INSERT, SELECT WITH GRANT OPTION');
```

has_sequence_privilege checks whether a user can access a sequence in a particular way. The possibilities for its arguments are analogous to has_table_privilege. The desired access privilege type must evaluate to one of USAGE, SELECT, or UPDATE.

has_any_column_privilege checks whether a user can access any column of a table in a particular way. Its argument possibilities are analogous to has_table_privilege, except that the desired access privilege type must evaluate to some combination of SELECT, INSERT, UPDATE, or REFERENCES. Note that having any of these privileges at the table level implicitly grants it for each column of the table, so has_any_column_privilege will always return true if has_table_privilege does for the same arguments. But has_any_column_privilege also succeeds if there is a column-level

grant of the privilege for at least one column.

`has_column_privilege` checks whether a user can access a column in a particular way. Its argument possibilities are analogous to `has_table_privilege`, with the addition that the column can be specified either by name or attribute number. The desired access privilege type must evaluate to some combination of `SELECT`, `INSERT`, `UPDATE`, or `REFERENCES`. Note that having any of these privileges at the table level implicitly grants it for each column of the table.

`has_database_privilege` checks whether a user can access a database in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to some combination of `CREATE`, `CONNECT`, `TEMPORARY`, or `TEMP` (which is equivalent to `TEMPORARY`).

`has_function_privilege` checks whether a user can access a function in a particular way. Its argument possibilities are analogous to `has_table_privilege`. When specifying a function by a text string rather than by OID, the allowed input is the same as for the `regprocedure` data type (see Section 8.18). The desired access privilege type must evaluate to `EXECUTE`. An example is:

```
SELECT has_function_privilege('joeuser', 'myfunc(int, text)', 'execute');
```

`has_foreign_data_wrapper_privilege` checks whether a user can access a foreign-data wrapper in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_language_privilege` checks whether a user can access a procedural language in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_schema_privilege` checks whether a user can access a schema in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to some combination of `CREATE` or `USAGE`.

`has_server_privilege` checks whether a user can access a foreign server in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `USAGE`.

`has_tablespace_privilege` checks whether a user can access a tablespace in a particular way. Its argument possibilities are analogous to `has_table_privilege`. The desired access privilege type must evaluate to `CREATE`.

`pg_has_role` checks whether a user can access a role in a particular way. Its argument possibilities are analogous to `has_table_privilege`, except that `public` is not allowed as a user name. The desired access privilege type must evaluate to some combination of `MEMBER` or `USAGE`. `MEMBER` denotes direct or indirect membership in the role (that is, the right to do `SET ROLE`), while `USAGE` denotes whether the privileges of the role are immediately available without doing `SET ROLE`.

Table 9-58 shows functions that determine whether a certain object is *visible* in the current schema search path. For example, a table is said to be visible if its containing schema is in the search path and no table of the same name appears earlier in the search path. This is equivalent to the statement that the table can be referenced by name without explicit schema qualification. To list the names of all visible tables:

```
SELECT relname FROM pg_class WHERE pg_table_is_visible(oid);
```

Table 9-58. Schema Visibility Inquiry Functions

Name	Return Type	Description
pg_collation_is_visible(collation_oid)	boolean	is collation visible in search path
pg_conversion_is_visible(conversion_oid)	boolean	is conversion visible in search path
pg_function_is_visible(function_oid)	boolean	is function visible in search path
pg_opclass_is_visible(opclass_oid)	boolean	is operator class visible in search path
pg_operator_is_visible(operator_oid)	boolean	is operator visible in search path
pg_opfamily_is_visible(opclass_oid)	boolean	is operator family visible in search path
pg_table_is_visible(table_oid)	boolean	is table visible in search path
pg_ts_config_is_visible(config_oid)	boolean	is text search configuration visible in search path
pg_ts_dict_is_visible(dict_oid)	boolean	is text search dictionary visible in search path
pg_ts_parser_is_visible(parser_oid)	boolean	is text search parser visible in search path
pg_ts_template_is_visible(template_oid)	boolean	is text search template visible in search path
pg_type_is_visible(type_oid)	boolean	is type (or domain) visible in search path

Each function performs the visibility check for one type of database object. Note that `pg_table_is_visible` can also be used with views, indexes and sequences; `pg_type_is_visible` can also be used with domains. For functions and operators, an object in the search path is visible if there is no object of the same name *and argument data type(s)* earlier in the path. For operator classes, both name and associated index access method are considered.

All these functions require object OIDs to identify the object to be checked. If you want to test an object by name, it is convenient to use the OID alias types (`regclass`, `regtype`, `regprocedure`, `regoperator`, `regconfig`, or `regdictionary`), for example:

```
SELECT pg_type_is_visible('myschema.widget'::regtype);
```

Note that it would not make much sense to test a non-schema-qualified type name in this way — if the name can be recognized at all, it must be visible.

Table 9-59 lists functions that extract information from the system catalogs.

Table 9-59. System Catalog Information Functions

Name	Return Type	Description
format_type(type_oid, typemod)	text	get SQL name of a data type

Name	Return Type	Description
pg_describe_object(catalog_id oid, object_id oid, object_sub_id integer)	text	get description of a database object
pg_identify_object(catalog_id oid, object_id oid, object_sub_id integer)	type text, schema text, name text, identity text	get identity of a database object
pg_get_constraintdef(constraint_oid)	text	get definition of a constraint
pg_get_constraintdef(constraint_oid, pretty_bool)	text	get definition of a constraint
pg_get_expr(pg_node_tree, relation_oid)	text	decompile internal form of an expression, assuming that any Vars in it refer to the relation indicated by the second parameter
pg_get_expr(pg_node_tree, relation_oid, pretty_bool)	text	decompile internal form of an expression, assuming that any Vars in it refer to the relation indicated by the second parameter
pg_get_functiondef(func_oid)	text	get definition of a function
pg_get_function_arguments(func_oid)	text	get argument list of function's definition (with default values)
pg_get_function_identity_arguments(func_oid)	text	get argument list to identify a function (without default values)
pg_get_function_result(func_oid)	text	get RETURNS clause for function
pg_get_indexdef(index_oid)	text	get CREATE INDEX command for index
pg_get_indexdef(index_oid, column_no, pretty_bool)	text	get CREATE INDEX command for index, or definition of just one index column when column_no is not zero
pg_get_keywords()	setof record	get list of SQL keywords and their categories
pg_get_ruledef(rule_oid)	text	get CREATE RULE command for rule
pg_get_ruledef(rule_oid, pretty_bool)	text	get CREATE RULE command for rule
pg_get_serial_sequence(table_name, column_name)	text	get name of the sequence that a serial, smallserial or bigserial column uses
pg_get_triggerdef(trigger_oid)	text	get CREATE [CONSTRAINT] TRIGGER command for trigger
pg_get_triggerdef(trigger_oid, pretty_bool)	text	get CREATE [CONSTRAINT] TRIGGER command for trigger

Name	Return Type	Description
pg_get_userbyid(role_oid)	name	get role name with given OID
pg_get_viewdef(view_name)	text	get underlying SELECT command for view or materialized view (*deprecated*)
pg_get_viewdef(view_name, pretty_bool)	text	get underlying SELECT command for view or materialized view (*deprecated*)
pg_get_viewdef(view_oid)	text	get underlying SELECT command for view or materialized view
pg_get_viewdef(view_oid, pretty_bool)	text	get underlying SELECT command for view or materialized view
pg_get_viewdef(view_oid, wrap_column_int)	text	get underlying SELECT command for view or materialized view; lines with fields are wrapped to specified number of columns, pretty-printing is implied
pg_options_to_table(reloptions)	setof record	get the set of storage option name/value pairs
pg_tablespace_databases(tablespace_oid)	setof oid	get the set of database OIDs that have objects in the tablespace
pg_tablespace_location(tablespace_oid)	text	get the path in the file system that this tablespace is located in
pg_typeof(any)	regtype	get the data type of any value
collation for (any)	text	get the collation of the argument
to_regclass(rel_name)	regclass	get the OID of the named relation
to_regproc(func_name)	regproc	get the OID of the named function
to_regprocedure(func_name)	regprocedure	get the OID of the named function
to_regoper(operator_name)	regoper	get the OID of the named operator
to_regoperator(operator_name)	regoperator	get the OID of the named operator
to_regtype(type_name)	regtype	get the OID of the named type

format_type returns the SQL name of a data type that is identified by its type OID and possibly a type modifier. Pass NULL for the type modifier if no specific modifier is known.

pg_get_keywords returns a set of records describing the SQL keywords recognized by the server. The word column contains the keyword. The catcode column contains a category code: U for unreserved, C for column name, T for type or function name, or R for reserved. The catdesc column contains a possibly-localized string describing the category.

`pg_get_constraintdef`, `pg_get_indexdef`, `pg_get_ruledef`, and `pg_get_triggerdef`, respectively reconstruct the creating command for a constraint, index, rule, or trigger. (Note that this is a decompiled reconstruction, not the original text of the command.) `pg_get_expr` decompiles the internal form of an individual expression, such as the default value for a column. It can be useful when examining the contents of system catalogs. If the expression might contain Vars, specify the OID of the relation they refer to as the second parameter; if no Vars are expected, zero is sufficient. `pg_get_viewdef` reconstructs the `SELECT` query that defines a view. Most of these functions come in two variants, one of which can optionally "pretty-print" the result. The pretty-printed format is more readable, but the default format is more likely to be interpreted the same way by future versions of PostgreSQL; avoid using pretty-printed output for dump purposes. Passing `false` for the pretty-print parameter yields the same result as the variant that does not have the parameter at all.

`pg_get_functiondef` returns a complete `CREATE OR REPLACE FUNCTION` statement for a function. `pg_get_function_arguments` returns the argument list of a function, in the form it would need to appear in within `CREATE FUNCTION`. `pg_get_function_result` similarly returns the appropriate `RETURNS` clause for the function. `pg_get_function_identity_arguments` returns the argument list necessary to identify a function, in the form it would need to appear in within `ALTER FUNCTION`, for instance. This form omits default values.

`pg_get_serial_sequence` returns the name of the sequence associated with a column, or NULL if no sequence is associated with the column. The first input parameter is a table name with optional schema, and the second parameter is a column name. Because the first parameter is potentially a schema and table, it is not treated as a double-quoted identifier, meaning it is lower cased by default, while the second parameter, being just a column name, is treated as double-quoted and has its case preserved. The function returns a value suitably formatted for passing to sequence functions (see Section 9.16). This association can be modified or removed with `ALTER SEQUENCE OWNED BY`. (The function probably should have been called `pg_get_owned_sequence`; its current name reflects the fact that it's typically used with `serial` or `bigserial` columns.)

`pg_get_userbyid` extracts a role's name given its OID.

`pg_options_to_table` returns the set of storage option name/value pairs (`option_name`/`option_value`) when passed `pg_class.reloptions` or `pg_attribute.attoptions`.

`pg_tablespace_databases` allows a tablespace to be examined. It returns the set of OIDs of databases that have objects stored in the tablespace. If this function returns any rows, the tablespace is not empty and cannot be dropped. To display the specific objects populating the tablespace, you will need to connect to the databases identified by `pg_tablespace_databases` and query their `pg_class` catalogs.

`pg_describe_object` returns a textual description of a database object specified by catalog OID, object OID and a (possibly zero) sub-object ID. This description is intended to be human-readable, and might be translated, depending on server configuration. This is useful to determine the identity of an object as stored in the `pg_depend` catalog.

`pg_identify_object` returns a row containing enough information to uniquely identify the database object specified by catalog OID, object OID and a (possibly zero) sub-object ID. This information is intended to be machine-readable, and is never translated. `type` identifies the type of database object; `schema` is the schema name that the object belongs in, or `NULL` for object types that do not belong to schemas; `name` is the name of the object, quoted if necessary, only present if it can be used (alongside schema name, if pertinent) as a unique identifier of the object, otherwise `NULL`; `identity` is the complete object identity, with the precise format depending on object type, and each part within the format being schema-qualified and quoted as necessary.

`pg_typeof` returns the OID of the data type of the value that is passed to it. This can be helpful

for troubleshooting or dynamically constructing SQL queries. The function is declared as returning `regtype`, which is an OID alias type (see Section 8.18); this means that it is the same as an OID for comparison purposes but displays as a type name. For example:

```
SELECT pg_typeof(33);

 pg_typeof
-----------
 integer
(1 row)

SELECT typlen FROM pg_type WHERE oid = pg_typeof(33);
 typlen
--------
      4
(1 row)
```

The expression `collation for` returns the collation of the value that is passed to it. Example:

```
SELECT collation for (description) FROM pg_description LIMIT 1;
 pg_collation_for
------------------
 "default"
(1 row)

SELECT collation for ('foo' COLLATE "de_DE");
 pg_collation_for
------------------
 "de_DE"
(1 row)
```

The value might be quoted and schema-qualified. If no collation is derived for the argument expression, then a null value is returned. If the argument is not of a collatable data type, then an error is raised.

The `to_regclass`, `to_regproc`, `to_regprocedure`, `to_regoper`, `to_regoperator`, and `to_regtype` functions translate relation, function, operator, and type names to objects of type `regclass`, `regproc`, `regprocedure`, `regoper`, `regoperator`, and `regtype`, respectively. These functions differ from a cast from text in that they don't accept a numeric OID, and that they return null rather than throwing an error if the name is not found (or, for `to_regproc` and `to_regoper`, if the given name matches multiple objects).

The functions shown in Table 9-60 extract comments previously stored with the COMMENT command. A null value is returned if no comment could be found for the specified parameters.

Table 9-60. Comment Information Functions

Name	Return Type	Description
`col_description(table_oid, column_number)`	`text`	get comment for a table column
`obj_description(object_oid, catalog_name)`	`text`	get comment for a database object
`obj_description(object_oid)`	`text`	get comment for a database object (*deprecated*)

Name	Return Type	Description
shobj_description(object_oid, catalog_name)	text	get comment for a shared database object

col_description returns the comment for a table column, which is specified by the OID of its table and its column number. (obj_description cannot be used for table columns since columns do not have OIDs of their own.)

The two-parameter form of obj_description returns the comment for a database object specified by its OID and the name of the containing system catalog. For example, obj_description(123456,'pg_class') would retrieve the comment for the table with OID 123456. The one-parameter form of obj_description requires only the object OID. It is deprecated since there is no guarantee that OIDs are unique across different system catalogs; therefore, the wrong comment might be returned.

shobj_description is used just like obj_description except it is used for retrieving comments on shared objects. Some system catalogs are global to all databases within each cluster, and the descriptions for objects in them are stored globally as well.

The functions shown in Table 9-61 provide server transaction information in an exportable form. The main use of these functions is to determine which transactions were committed between two snapshots.

Table 9-61. Transaction IDs and Snapshots

Name	Return Type	Description
txid_current()	bigint	get current transaction ID
txid_current_snapshot()	txid_snapshot	get current snapshot
txid_snapshot_xip(txid_snapshot)	setof bigint	get in-progress transaction IDs in snapshot
txid_snapshot_xmax(txid_snapshot)	bigint	get xmax of snapshot
txid_snapshot_xmin(txid_snapshot)	bigint	get xmin of snapshot
txid_visible_in_snapshot(bigint, txid_snapshot)	boolean	is transaction ID visible in snapshot? (do not use with subtransaction ids)

The internal transaction ID type (xid) is 32 bits wide and wraps around every 4 billion transactions. However, these functions export a 64-bit format that is extended with an "epoch" counter so it will not wrap around during the life of an installation. The data type used by these functions, txid_snapshot, stores information about transaction ID visibility at a particular moment in time. Its components are described in Table 9-62.

Table 9-62. Snapshot Components

Name	Description
xmin	Earliest transaction ID (txid) that is still active. All earlier transactions will either be committed and visible, or rolled back and dead.

Name	Description
xmax	First as-yet-unassigned txid. All txids greater than or equal to this are not yet started as of the time of the snapshot, and thus invisible.
xip_list	Active txids at the time of the snapshot. The list includes only those active txids between xmin and xmax; there might be active txids higher than xmax. A txid that is xmin <= txid < xmax and not in this list was already completed at the time of the snapshot, and thus either visible or dead according to its commit status. The list does not include txids of subtransactions.

txid_snapshot's textual representation is *xmin*:*xmax*:*xip_list*. For example 10:20:10,14,15 means xmin=10, xmax=20, xip_list=10, 14, 15.

9.26. System Administration Functions

The functions described in this section are used to control and monitor a PostgreSQL installation.

9.26.1. Configuration Settings Functions

Table 9-63 shows the functions available to query and alter run-time configuration parameters.

Table 9-63. Configuration Settings Functions

Name	Return Type	Description
current_setting(setting_name)	text	get current value of setting
set_config(setting_name, new_value, is_local)	text	set parameter and return new value

The function current_setting yields the current value of the setting setting_name. It corresponds to the SQL command SHOW. An example:

```
SELECT current_setting('datestyle');

 current_setting
-----------------
 ISO, MDY
(1 row)
```

set_config sets the parameter setting_name to new_value. If is_local is true, the new value will only apply to the current transaction. If you want the new value to apply for the current session, use false instead. The function corresponds to the SQL command SET. An example:

```
SELECT set_config('log_statement_stats', 'off', false);
```

```
 set_config
------------
 off
(1 row)
```

9.26.2. Server Signaling Functions

The functions shown in Table 9-64 send control signals to other server processes. Use of these functions is usually restricted to superusers, with noted exceptions.

Table 9-64. Server Signaling Functions

Name	Return Type	Description
`pg_cancel_backend(pid int)`	`boolean`	Cancel a backend's current query. You can execute this against another backend that has exactly the same role as the user calling the function. In all other cases, you must be a superuser.
`pg_reload_conf()`	`boolean`	Cause server processes to reload their configuration files
`pg_rotate_logfile()`	`boolean`	Rotate server's log file
`pg_terminate_backend(pid int)`	`boolean`	Terminate a backend. You can execute this against another backend that has exactly the same role as the user calling the function. In all other cases, you must be a superuser.

Each of these functions returns `true` if successful and `false` otherwise.

`pg_cancel_backend` and `pg_terminate_backend` send signals (SIGINT or SIGTERM respectively) to backend processes identified by process ID. The process ID of an active backend can be found from the `pid` column of the `pg_stat_activity` view, or by listing the `postgres` processes on the server (using ps on Unix or the Task Manager on Windows). The role of an active backend can be found from the `usename` column of the `pg_stat_activity` view.

`pg_reload_conf` sends a SIGHUP signal to the server, causing configuration files to be reloaded by all server processes.

`pg_rotate_logfile` signals the log-file manager to switch to a new output file immediately. This works only when the built-in log collector is running, since otherwise there is no log-file manager subprocess.

9.26.3. Backup Control Functions

The functions shown in Table 9-65 assist in making on-line backups. These functions cannot be executed during recovery (except `pg_is_in_backup`, `pg_backup_start_time` and

pg_xlog_location_diff).

Table 9-65. Backup Control Functions

Name	Return Type	Description
pg_create_restore_point(name text)	pg_lsn	Create a named point for performing restore (restricted to superusers)
pg_current_xlog_insert_location()	pg_lsn	Get current transaction log insert location
pg_current_xlog_location()	pg_lsn	Get current transaction log write location
pg_start_backup(label text [, fast boolean])	pg_lsn	Prepare for performing on-line backup (restricted to superusers or replication roles)
pg_stop_backup()	pg_lsn	Finish performing on-line backup (restricted to superusers or replication roles)
pg_is_in_backup()	bool	True if an on-line exclusive backup is still in progress.
pg_backup_start_time()	timestamp with time zone	Get start time of an on-line exclusive backup in progress.
pg_switch_xlog()	pg_lsn	Force switch to a new transaction log file (restricted to superusers)
pg_xlogfile_name(location pg_lsn)	text	Convert transaction log location string to file name
pg_xlogfile_name_offset(location pg_lsn)	text, integer	Convert transaction log location string to file name and decimal byte offset within file
pg_xlog_location_diff(location pg_lsn, location pg_lsn)	numeric	Calculate the difference between two transaction log locations

pg_start_backup accepts an arbitrary user-defined label for the backup. (Typically this would be the name under which the backup dump file will be stored.) The function writes a backup label file (backup_label) into the database cluster's data directory, performs a checkpoint, and then returns the backup's starting transaction log location as text. The user can ignore this result value, but it is provided in case it is useful.

```
postgres=# select pg_start_backup('label_goes_here');
 pg_start_backup
-----------------
 0/D4445B8
(1 row)
```

There is an optional second parameter of type boolean. If true, it specifies executing pg_start_backup as quickly as possible. This forces an immediate checkpoint which will cause a

spike in I/O operations, slowing any concurrently executing queries.

pg_stop_backup removes the label file created by pg_start_backup, and creates a backup history file in the transaction log archive area. The history file includes the label given to pg_start_backup, the starting and ending transaction log locations for the backup, and the starting and ending times of the backup. The return value is the backup's ending transaction log location (which again can be ignored). After recording the ending location, the current transaction log insertion point is automatically advanced to the next transaction log file, so that the ending transaction log file can be archived immediately to complete the backup.

pg_switch_xlog moves to the next transaction log file, allowing the current file to be archived (assuming you are using continuous archiving). The return value is the ending transaction log location + 1 within the just-completed transaction log file. If there has been no transaction log activity since the last transaction log switch, pg_switch_xlog does nothing and returns the start location of the transaction log file currently in use.

pg_create_restore_point creates a named transaction log record that can be used as recovery target, and returns the corresponding transaction log location. The given name can then be used with recovery_target_name to specify the point up to which recovery will proceed. Avoid creating multiple restore points with the same name, since recovery will stop at the first one whose name matches the recovery target.

pg_current_xlog_location displays the current transaction log write location in the same format used by the above functions. Similarly, pg_current_xlog_insert_location displays the current transaction log insertion point. The insertion point is the "logical" end of the transaction log at any instant, while the write location is the end of what has actually been written out from the server's internal buffers. The write location is the end of what can be examined from outside the server, and is usually what you want if you are interested in archiving partially-complete transaction log files. The insertion point is made available primarily for server debugging purposes. These are both read-only operations and do not require superuser permissions.

You can use pg_xlogfile_name_offset to extract the corresponding transaction log file name and byte offset from the results of any of the above functions. For example:

```
postgres=# SELECT * FROM pg_xlogfile_name_offset(pg_stop_backup());
         file_name          | file_offset
----------------------------+-------------
 00000001000000000000000D |     4039624
(1 row)
```

Similarly, pg_xlogfile_name extracts just the transaction log file name. When the given transaction log location is exactly at a transaction log file boundary, both these functions return the name of the preceding transaction log file. This is usually the desired behavior for managing transaction log archiving behavior, since the preceding file is the last one that currently needs to be archived.

pg_xlog_location_diff calculates the difference in bytes between two transaction log locations. It can be used with pg_stat_replication or some functions shown in Table 9-65 to get the replication lag.

For details about proper usage of these functions, see Section 24.3.

9.26.4. Recovery Control Functions

The functions shown in Table 9-66 provide information about the current status of the standby. These functions may be executed both during recovery and in normal running.

Table 9-66. Recovery Information Functions

Name	Return Type	Description
`pg_is_in_recovery()`	`bool`	True if recovery is still in progress.
`pg_last_xlog_receive_location()`	`pg_lsn`	Get last transaction log location received and synced to disk by streaming replication. While streaming replication is in progress this will increase monotonically. If recovery has completed this will remain static at the value of the last WAL record received and synced to disk during recovery. If streaming replication is disabled, or if it has not yet started, the function returns NULL.
`pg_last_xlog_replay_location()`	`pg_lsn`	Get last transaction log location replayed during recovery. If recovery is still in progress this will increase monotonically. If recovery has completed then this value will remain static at the value of the last WAL record applied during that recovery. When the server has been started normally without recovery the function returns NULL.
`pg_last_xact_replay_timestamp()`	`timestamp with time zone`	Get time stamp of last transaction replayed during recovery. This is the time at which the commit or abort WAL record for that transaction was generated on the primary. If no transactions have been replayed during recovery, this function returns NULL. Otherwise, if recovery is still in progress this will increase monotonically. If recovery has completed then this value will remain static at the value of the last transaction applied during that recovery. When the server has been started normally without recovery the function returns NULL.

The functions shown in Table 9-67 control the progress of recovery. These functions may be executed only during recovery.

Table 9-67. Recovery Control Functions

Name	Return Type	Description
`pg_is_xlog_replay_paused()`	`bool`	True if recovery is paused.
`pg_xlog_replay_pause()`	`void`	Pauses recovery immediately (restricted to superusers).
`pg_xlog_replay_resume()`	`void`	Restarts recovery if it was paused (restricted to superusers).

While recovery is paused no further database changes are applied. If in hot standby, all new queries will see the same consistent snapshot of the database, and no further query conflicts will be generated until recovery is resumed.

If streaming replication is disabled, the paused state may continue indefinitely without problem. While streaming replication is in progress WAL records will continue to be received, which will eventually fill available disk space, depending upon the duration of the pause, the rate of WAL generation and available disk space.

9.26.5. Snapshot Synchronization Functions

PostgreSQL allows database sessions to synchronize their snapshots. A *snapshot* determines which data is visible to the transaction that is using the snapshot. Synchronized snapshots are necessary when two or more sessions need to see identical content in the database. If two sessions just start their transactions independently, there is always a possibility that some third transaction commits between the executions of the two `START TRANSACTION` commands, so that one session sees the effects of that transaction and the other does not.

To solve this problem, PostgreSQL allows a transaction to *export* the snapshot it is using. As long as the exporting transaction remains open, other transactions can *import* its snapshot, and thereby be guaranteed that they see exactly the same view of the database that the first transaction sees. But note that any database changes made by any one of these transactions remain invisible to the other transactions, as is usual for changes made by uncommitted transactions. So the transactions are synchronized with respect to pre-existing data, but act normally for changes they make themselves.

Snapshots are exported with the `pg_export_snapshot` function, shown in Table 9-68, and imported with the SET TRANSACTION command.

Table 9-68. Snapshot Synchronization Functions

Name	Return Type	Description
`pg_export_snapshot()`	`text`	Save the current snapshot and return its identifier

The function `pg_export_snapshot` saves the current snapshot and returns a `text` string identifying the snapshot. This string must be passed (outside the database) to clients that want to import the snapshot. The snapshot is available for import only until the end of the transaction that exported it. A

transaction can export more than one snapshot, if needed. Note that doing so is only useful in `READ COMMITTED` transactions, since in `REPEATABLE READ` and higher isolation levels, transactions use the same snapshot throughout their lifetime. Once a transaction has exported any snapshots, it cannot be prepared with PREPARE TRANSACTION.

See SET TRANSACTION for details of how to use an exported snapshot.

9.26.6. Replication Functions

The functions shown in Table 9-69 are for controlling and interacting with replication features. See Section 25.2.5 and Section 25.2.6 for information about the underlying features. Use of these functions is restricted to superusers.

Many of these functions have equivalent commands in the replication protocol; see Section 49.3.

The functions described in Section 9.26.5, Section 9.26.4, and Section 9.26.3 are also relevant for replication.

Table 9-69. Replication SQL Functions

Function	Return Type	Description
`pg_create_physical_replication_slot(slot_name name)`	`(slot_name name, xlog_position pg_lsn)`	Creates a new physical replication slot named `slot_name`. Streaming changes from a physical slot is only possible with the streaming-replication protocol - see Section 49.3. Corresponds to the replication protocol command `CREATE_REPLICATION_SLOT ... PHYSICAL`.
`pg_drop_replication_slot(slot_name name)`	`void`	Drops the physical or logical replication slot named `slot_name`. Same as replication protocol command `DROP_REPLICATION_SLOT`.
`pg_create_logical_replication_slot(slot_name name, plugin name)`	`(slot_name name, xlog_position pg_lsn)`	Creates a new logical (decoding) replication slot named `slot_name` using the output plugin `plugin`. A call to this function has the same effect as the replication protocol command `CREATE_REPLICATION_SLOT ... LOGICAL`.

Function	Return Type	Description
pg_logical_slot_get_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])	(location pg_lsn, xid xid, data text)	Returns changes in the slot slot_name, starting from the point at which since changes have been consumed last. If upto_lsn and upto_nchanges are NULL, logical decoding will continue until end of WAL. If upto_lsn is non-NULL, decoding will include only those transactions which commit prior to the specified LSN. If upto_nchanges is non-NULL, decoding will stop when the number of rows produced by decoding exceeds the specified value. Note, however, that the actual number of rows returned may be larger, since this limit is only checked after adding the rows produced when decoding each new transaction commit.
pg_logical_slot_peek_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])	(location text, xid xid, data text)	Behaves just like the pg_logical_slot_get_changes() function, except that changes are not consumed; that is, they will be returned again on future calls.
pg_logical_slot_get_binary_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])	(location pg_lsn, xid xid, data bytea)	Behaves just like the pg_logical_slot_get_changes() function, except that changes are returned as bytea.
pg_logical_slot_peek_binary_changes(slot_name name, upto_lsn pg_lsn, upto_nchanges int, VARIADIC options text[])	(location pg_lsn, xid xid, data bytea)	Behaves just like the pg_logical_slot_get_changes() function, except that changes are returned as bytea and that changes are not consumed; that is, they will be returned again on future calls.

9.26.7. Database Object Management Functions

The functions shown in Table 9-70 calculate the disk space usage of database objects.

Table 9-70. Database Object Size Functions

Name	Return Type	Description
pg_column_size(any)	int	Number of bytes used to store a particular value (possibly compressed)
pg_database_size(oid)	bigint	Disk space used by the database with the specified OID
pg_database_size(name)	bigint	Disk space used by the database with the specified name
pg_indexes_size(regclass)	bigint	Total disk space used by indexes attached to the specified table
pg_relation_size(relation regclass, fork text)	bigint	Disk space used by the specified fork ('main', 'fsm', 'vm', or 'init') of the specified table or index
pg_relation_size(relation regclass)	bigint	Shorthand for pg_relation_size(..., 'main')
pg_size_pretty(bigint)	text	Converts a size in bytes expressed as a 64-bit integer into a human-readable format with size units
pg_size_pretty(numeric)	text	Converts a size in bytes expressed as a numeric value into a human-readable format with size units
pg_table_size(regclass)	bigint	Disk space used by the specified table, excluding indexes (but including TOAST, free space map, and visibility map)
pg_tablespace_size(oid)	bigint	Disk space used by the tablespace with the specified OID
pg_tablespace_size(name)	bigint	Disk space used by the tablespace with the specified name
pg_total_relation_size(regclass)	bigint	Total disk space used by the specified table, including all indexes and TOAST data

pg_column_size shows the space used to store any individual data value.

pg_total_relation_size accepts the OID or name of a table or toast table, and returns the total on-disk space used for that table, including all associated indexes. This function is equivalent to pg_table_size + pg_indexes_size.

pg_table_size accepts the OID or name of a table and returns the disk space needed for that table, exclusive of indexes. (TOAST space, free space map, and visibility map are included.)

pg_indexes_size accepts the OID or name of a table and returns the total disk space used by all

the indexes attached to that table.

pg_database_size and pg_tablespace_size accept the OID or name of a database or tablespace, and return the total disk space used therein. To use pg_database_size, you must have CONNECT permission on the specified database (which is granted by default). To use pg_tablespace_size, you must have CREATE permission on the specified tablespace, unless it is the default tablespace for the current database.

pg_relation_size accepts the OID or name of a table, index or toast table, and returns the on-disk size in bytes of one fork of that relation. (Note that for most purposes it is more convenient to use the higher-level functions pg_total_relation_size or pg_table_size, which sum the sizes of all forks.) With one argument, it returns the size of the main data fork of the relation. The second argument can be provided to specify which fork to examine:

- 'main' returns the size of the main data fork of the relation.
- 'fsm' returns the size of the Free Space Map (see Section 59.3) associated with the relation.
- 'vm' returns the size of the Visibility Map (see Section 59.4) associated with the relation.
- 'init' returns the size of the initialization fork, if any, associated with the relation.

pg_size_pretty can be used to format the result of one of the other functions in a human-readable way, using kB, MB, GB or TB as appropriate.

The functions above that operate on tables or indexes accept a regclass argument, which is simply the OID of the table or index in the pg_class system catalog. You do not have to look up the OID by hand, however, since the regclass data type's input converter will do the work for you. Just write the table name enclosed in single quotes so that it looks like a literal constant. For compatibility with the handling of ordinary SQL names, the string will be converted to lower case unless it contains double quotes around the table name.

If an OID that does not represent an existing object is passed as argument to one of the above functions, NULL is returned.

The functions shown in Table 9-71 assist in identifying the specific disk files associated with database objects.

Table 9-71. Database Object Location Functions

Name	Return Type	Description
pg_relation_filenode(relation regclass)	oid	Filenode number of the specified relation
pg_relation_filepath(relation regclass)	text	File path name of the specified relation
pg_filenode_relation(tablespace oid, filenode oid)	regclass	Find the relation associated with a given tablespace and filenode

pg_relation_filenode accepts the OID or name of a table, index, sequence, or toast table, and returns the "filenode" number currently assigned to it. The filenode is the base component of the file name(s) used for the relation (see Section 59.1 for more information). For most tables the result is the same as pg_class.relfilenode, but for certain system catalogs relfilenode is zero and this function must be used to get the correct value. The function returns NULL if passed a relation that

does not have storage, such as a view.

pg_relation_filepath is similar to pg_relation_filenode, but it returns the entire file path name (relative to the database cluster's data directory PGDATA) of the relation.

pg_filenode_relation is the reverse of pg_relation_filenode. Given a "tablespace" OID and a "filenode", it returns the associated relation's OID. For a table in the database's default tablespace, the tablespace can be specified as 0.

9.26.8. Generic File Access Functions

The functions shown in Table 9-72 provide native access to files on the machine hosting the server. Only files within the database cluster directory and the log_directory can be accessed. Use a relative path for files in the cluster directory, and a path matching the log_directory configuration setting for log files. Use of these functions is restricted to superusers.

Table 9-72. Generic File Access Functions

Name	Return Type	Description
pg_ls_dir(dirname text)	setof text	List the contents of a directory
pg_read_file(filename text [, offset bigint, length bigint])	text	Return the contents of a text file
pg_read_binary_file(filename text [, offset bigint, length bigint])	bytea	Return the contents of a file
pg_stat_file(filename text)	record	Return information about a file

pg_ls_dir returns all the names in the specified directory, except the special entries "." and "..".

pg_read_file returns part of a text file, starting at the given offset, returning at most length bytes (less if the end of file is reached first). If offset is negative, it is relative to the end of the file. If offset and length are omitted, the entire file is returned. The bytes read from the file are interpreted as a string in the server encoding; an error is thrown if they are not valid in that encoding.

pg_read_binary_file is similar to pg_read_file, except that the result is a bytea value; accordingly, no encoding checks are performed. In combination with the convert_from function, this function can be used to read a file in a specified encoding:

```
SELECT convert_from(pg_read_binary_file('file_in_utf8.txt'), 'UTF8');
```

pg_stat_file returns a record containing the file size, last accessed time stamp, last modified time stamp, last file status change time stamp (Unix platforms only), file creation time stamp (Windows only), and a boolean indicating if it is a directory. Typical usages include:

```
SELECT * FROM pg_stat_file('filename');
SELECT (pg_stat_file('filename')).modification;
```

9.26.9. Advisory Lock Functions

The functions shown in Table 9-73 manage advisory locks. For details about proper use of these functions, see Section 13.3.5.

Table 9-73. Advisory Lock Functions

Name	Return Type	Description
`pg_advisory_lock(key bigint)`	`void`	Obtain exclusive session level advisory lock
`pg_advisory_lock(key1 int, key2 int)`	`void`	Obtain exclusive session level advisory lock
`pg_advisory_lock_shared(key bigint)`	`void`	Obtain shared session level advisory lock
`pg_advisory_lock_shared(key1 int, key2 int)`	`void`	Obtain shared session level advisory lock
`pg_advisory_unlock(key bigint)`	`boolean`	Release an exclusive session level advisory lock
`pg_advisory_unlock(key1 int, key2 int)`	`boolean`	Release an exclusive session level advisory lock
`pg_advisory_unlock_all()`	`void`	Release all session level advisory locks held by the current session
`pg_advisory_unlock_shared(key bigint)`	`boolean`	Release a shared session level advisory lock
`pg_advisory_unlock_shared(key1 int, key2 int)`	`boolean`	Release a shared session level advisory lock
`pg_advisory_xact_lock(key bigint)`	`void`	Obtain exclusive transaction level advisory lock
`pg_advisory_xact_lock(key1 int, key2 int)`	`void`	Obtain exclusive transaction level advisory lock
`pg_advisory_xact_lock_shared(key bigint)`	`void`	Obtain shared transaction level advisory lock
`pg_advisory_xact_lock_shared(key1 int, key2 int)`	`void`	Obtain shared transaction level advisory lock
`pg_try_advisory_lock(key bigint)`	`boolean`	Obtain exclusive session level advisory lock if available
`pg_try_advisory_lock(key1 int, key2 int)`	`boolean`	Obtain exclusive session level advisory lock if available
`pg_try_advisory_lock_shared(key bigint)`	`boolean`	Obtain shared session level advisory lock if available

Name	Return Type	Description
pg_try_advisory_lock_shared(key1 int, key2 int)	boolean	Obtain shared session level advisory lock if available
pg_try_advisory_xact_lock(key bigint)	boolean	Obtain exclusive transaction level advisory lock if available
pg_try_advisory_xact_lock(key1 int, key2 int)	boolean	Obtain exclusive transaction level advisory lock if available
pg_try_advisory_xact_lock_shared(key bigint)	boolean	Obtain shared transaction level advisory lock if available
pg_try_advisory_xact_lock_shared(key1 int, key2 int)	boolean	Obtain shared transaction level advisory lock if available

pg_advisory_lock locks an application-defined resource, which can be identified either by a single 64-bit key value or two 32-bit key values (note that these two key spaces do not overlap). If another session already holds a lock on the same resource identifier, this function will wait until the resource becomes available. The lock is exclusive. Multiple lock requests stack, so that if the same resource is locked three times it must then be unlocked three times to be released for other sessions' use.

pg_advisory_lock_shared works the same as pg_advisory_lock, except the lock can be shared with other sessions requesting shared locks. Only would-be exclusive lockers are locked out.

pg_try_advisory_lock is similar to pg_advisory_lock, except the function will not wait for the lock to become available. It will either obtain the lock immediately and return true, or return false if the lock cannot be acquired immediately.

pg_try_advisory_lock_shared works the same as pg_try_advisory_lock, except it attempts to acquire a shared rather than an exclusive lock.

pg_advisory_unlock will release a previously-acquired exclusive session level advisory lock. It returns true if the lock is successfully released. If the lock was not held, it will return false, and in addition, an SQL warning will be reported by the server.

pg_advisory_unlock_shared works the same as pg_advisory_unlock, except it releases a shared session level advisory lock.

pg_advisory_unlock_all will release all session level advisory locks held by the current session. (This function is implicitly invoked at session end, even if the client disconnects ungracefully.)

pg_advisory_xact_lock works the same as pg_advisory_lock, except the lock is automatically released at the end of the current transaction and cannot be released explicitly.

pg_advisory_xact_lock_shared works the same as pg_advisory_lock_shared, except the lock is automatically released at the end of the current transaction and cannot be released explicitly.

pg_try_advisory_xact_lock works the same as pg_try_advisory_lock, except the lock, if acquired, is automatically released at the end of the current transaction and cannot be released explicitly.

pg_try_advisory_xact_lock_shared works the same as pg_try_advisory_lock_shared, except the lock, if acquired, is automatically released at the end of the current transaction and cannot be released explicitly.

9.27. Trigger Functions

Currently PostgreSQL provides one built in trigger function, `suppress_redundant_updates_trigger`, which will prevent any update that does not actually change the data in the row from taking place, in contrast to the normal behavior which always performs the update regardless of whether or not the data has changed. (This normal behavior makes updates run faster, since no checking is required, and is also useful in certain cases.)

Ideally, you should normally avoid running updates that don't actually change the data in the record. Redundant updates can cost considerable unnecessary time, especially if there are lots of indexes to alter, and space in dead rows that will eventually have to be vacuumed. However, detecting such situations in client code is not always easy, or even possible, and writing expressions to detect them can be error-prone. An alternative is to use `suppress_redundant_updates_trigger`, which will skip updates that don't change the data. You should use this with care, however. The trigger takes a small but non-trivial time for each record, so if most of the records affected by an update are actually changed, use of this trigger will actually make the update run slower.

The `suppress_redundant_updates_trigger` function can be added to a table like this:

```
CREATE TRIGGER z_min_update
BEFORE UPDATE ON tablename
FOR EACH ROW EXECUTE PROCEDURE suppress_redundant_updates_trigger();
```

In most cases, you would want to fire this trigger last for each row. Bearing in mind that triggers fire in name order, you would then choose a trigger name that comes after the name of any other trigger you might have on the table.

For more information about creating triggers, see CREATE TRIGGER.

9.28. Event Trigger Functions

Currently PostgreSQL provides one built-in event trigger helper function, `pg_event_trigger_dropped_objects`.

`pg_event_trigger_dropped_objects` returns a list of all objects dropped by the command in whose `sql_drop` event it is called. If called in any other context, `pg_event_trigger_dropped_objects` raises an error. `pg_event_trigger_dropped_objects` returns the following columns:

Name	Type	Description
`classid`	`Oid`	OID of catalog the object belonged in
`objid`	`Oid`	OID the object had within the catalog
`objsubid`	`int32`	Object sub-id (e.g. attribute number for columns)
`object_type`	`text`	Type of the object
`schema_name`	`text`	Name of the schema the object belonged in, if any; otherwise `NULL`. No quoting is applied.

Name	Type	Description
object_name	text	Name of the object, if the combination of schema and name can be used as a unique identifier for the object; otherwise NULL. No quoting is applied, and name is never schema-qualified.
object_identity	text	Text rendering of the object identity, schema-qualified. Each and every identifier present in the identity is quoted if necessary.

The pg_event_trigger_dropped_objects function can be used in an event trigger like this:

```
CREATE FUNCTION test_event_trigger_for_drops()
        RETURNS event_trigger LANGUAGE plpgsql AS $$
DECLARE
    obj record;
BEGIN
    FOR obj IN SELECT * FROM pg_event_trigger_dropped_objects()
    LOOP
        RAISE NOTICE '% dropped object: % %.% %',
                     tg_tag,
                     obj.object_type,
                     obj.schema_name,
                     obj.object_name,
                     obj.object_identity;
    END LOOP;
END
$$;
CREATE EVENT TRIGGER test_event_trigger_for_drops
   ON sql_drop
   EXECUTE PROCEDURE test_event_trigger_for_drops();
```

For more information about event triggers, see Chapter 37.

Chapter 10. Type Conversion

SQL statements can, intentionally or not, require the mixing of different data types in the same expression. PostgreSQL has extensive facilities for evaluating mixed-type expressions.

In many cases a user does not need to understand the details of the type conversion mechanism. However, implicit conversions done by PostgreSQL can affect the results of a query. When necessary, these results can be tailored by using *explicit* type conversion.

This chapter introduces the PostgreSQL type conversion mechanisms and conventions. Refer to the relevant sections in Chapter 8 and Chapter 9 for more information on specific data types and allowed functions and operators.

10.1. Overview

SQL is a strongly typed language. That is, every data item has an associated data type which determines its behavior and allowed usage. PostgreSQL has an extensible type system that is more general and flexible than other SQL implementations. Hence, most type conversion behavior in PostgreSQL is governed by general rules rather than by *ad hoc* heuristics. This allows the use of mixed-type expressions even with user-defined types.

The PostgreSQL scanner/parser divides lexical elements into five fundamental categories: integers, non-integer numbers, strings, identifiers, and key words. Constants of most non-numeric types are first classified as strings. The SQL language definition allows specifying type names with strings, and this mechanism can be used in PostgreSQL to start the parser down the correct path. For example, the query:

```
SELECT text 'Origin' AS "label", point '(0,0)' AS "value";

 label  | value
--------+-------
 Origin | (0,0)
(1 row)
```

has two literal constants, of type `text` and `point`. If a type is not specified for a string literal, then the placeholder type `unknown` is assigned initially, to be resolved in later stages as described below.

There are four fundamental SQL constructs requiring distinct type conversion rules in the PostgreSQL parser:

Function calls

Much of the PostgreSQL type system is built around a rich set of functions. Functions can have one or more arguments. Since PostgreSQL permits function overloading, the function name alone does not uniquely identify the function to be called; the parser must select the right function based on the data types of the supplied arguments.

Operators

PostgreSQL allows expressions with prefix and postfix unary (one-argument) operators, as well as binary (two-argument) operators. Like functions, operators can be overloaded, so the same problem of selecting the right operator exists.

Value Storage

SQL INSERT and UPDATE statements place the results of expressions into a table. The expressions in the statement must be matched up with, and perhaps converted to, the types of the target columns.

UNION, CASE, and related constructs

Since all query results from a unionized SELECT statement must appear in a single set of columns, the types of the results of each SELECT clause must be matched up and converted to a uniform set. Similarly, the result expressions of a CASE construct must be converted to a common type so that the CASE expression as a whole has a known output type. The same holds for ARRAY constructs, and for the GREATEST and LEAST functions.

The system catalogs store information about which conversions, or *casts*, exist between which data types, and how to perform those conversions. Additional casts can be added by the user with the CREATE CAST command. (This is usually done in conjunction with defining new data types. The set of casts between built-in types has been carefully crafted and is best not altered.)

An additional heuristic provided by the parser allows improved determination of the proper casting behavior among groups of types that have implicit casts. Data types are divided into several basic *type categories*, including boolean, numeric, string, bitstring, datetime, timespan, geometric, network, and user-defined. (For a list see Table 48-53; but note it is also possible to create custom type categories.) Within each category there can be one or more *preferred types*, which are preferred when there is a choice of possible types. With careful selection of preferred types and available implicit casts, it is possible to ensure that ambiguous expressions (those with multiple candidate parsing solutions) can be resolved in a useful way.

All type conversion rules are designed with several principles in mind:

- Implicit conversions should never have surprising or unpredictable outcomes.
- There should be no extra overhead in the parser or executor if a query does not need implicit type conversion. That is, if a query is well-formed and the types already match, then the query should execute without spending extra time in the parser and without introducing unnecessary implicit conversion calls in the query.
- Additionally, if a query usually requires an implicit conversion for a function, and if then the user defines a new function with the correct argument types, the parser should use this new function and no longer do implicit conversion to use the old function.

10.2. Operators

The specific operator that is referenced by an operator expression is determined using the following procedure. Note that this procedure is indirectly affected by the precedence of the operators involved, since that will determine which sub-expressions are taken to be the inputs of which operators. See Section 4.1.6 for more information.

Operator Type Resolution

1. Select the operators to be considered from the pg_operator system catalog. If a non-schema-qualified operator name was used (the usual case), the operators considered are those with the

matching name and argument count that are visible in the current search path (see Section 5.7.3). If a qualified operator name was given, only operators in the specified schema are considered.

   a. If the search path finds multiple operators with identical argument types, only the one appearing earliest in the path is considered. Operators with different argument types are considered on an equal footing regardless of search path position.

2. Check for an operator accepting exactly the input argument types. If one exists (there can be only one exact match in the set of operators considered), use it.

   a. If one argument of a binary operator invocation is of the `unknown` type, then assume it is the same type as the other argument for this check. Invocations involving two `unknown` inputs, or a unary operator with an `unknown` input, will never find a match at this step.

   b. If one argument of a binary operator invocation is of the `unknown` type and the other is of a domain type, next check to see if there is an operator accepting exactly the domain's base type on both sides; if so, use it.

3. Look for the best match.

   a. Discard candidate operators for which the input types do not match and cannot be converted (using an implicit conversion) to match. `unknown` literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.

   b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-operator resolution.

   c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.

   d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.

   e. If any input arguments are `unknown`, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an unknown-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.

   f. If there are both `unknown` and known-type arguments, and all the known-type arguments have the same type, assume that the `unknown` arguments are also of that type, and check which candidates can accept that type at the `unknown`-argument positions. If exactly one candidate passes this test, use it. Otherwise, fail.

Some examples follow.

Example 10-1. Factorial Operator Type Resolution

There is only one factorial operator (postfix `!`) defined in the standard catalog, and it takes an argument of type `bigint`. The scanner assigns an initial type of `integer` to the argument in this query expression:

```
SELECT 40 ! AS "40 factorial";

                  40 factorial
-----------------------------------------------
 815915283247897734345611269596115894272000000000
(1 row)
```

So the parser does a type conversion on the operand and the query is equivalent to:

```
SELECT CAST(40 AS bigint) ! AS "40 factorial";
```

Example 10-2. String Concatenation Operator Type Resolution

A string-like syntax is used for working with string types and for working with complex extension types. Strings with unspecified type are matched with likely operator candidates.

An example with one unspecified argument:

```
SELECT text 'abc' || 'def' AS "text and unknown";

 text and unknown
------------------
 abcdef
(1 row)
```

In this case the parser looks to see if there is an operator taking `text` for both arguments. Since there is, it assumes that the second argument should be interpreted as type `text`.

Here is a concatenation of two values of unspecified types:

```
SELECT 'abc' || 'def' AS "unspecified";

 unspecified
-------------
 abcdef
(1 row)
```

In this case there is no initial hint for which type to use, since no types are specified in the query. So, the parser looks for all candidate operators and finds that there are candidates accepting both string-category and bit-string-category inputs. Since string category is preferred when available, that category is selected, and then the preferred type for strings, `text`, is used as the specific type to resolve the unknown-type literals as.

Example 10-3. Absolute-Value and Negation Operator Type Resolution

The PostgreSQL operator catalog has several entries for the prefix operator `@`, all of which implement absolute-value operations for various numeric data types. One of these entries is for type `float8`, which is the preferred type in the numeric category. Therefore, PostgreSQL will use that entry when faced with an `unknown` input:

```
SELECT @ '-4.5' AS "abs";
```

```
 abs
-----
 4.5
(1 row)
```

Here the system has implicitly resolved the unknown-type literal as type `float8` before applying the chosen operator. We can verify that `float8` and not some other type was used:

```
SELECT @ '-4.5e500' AS "abs";

ERROR:  "-4.5e500" is out of range for type double precision
```

On the other hand, the prefix operator ~ (bitwise negation) is defined only for integer data types, not for `float8`. So, if we try a similar case with ~, we get:

```
SELECT ~ '20' AS "negation";

ERROR:  operator is not unique: ~ "unknown"
HINT:  Could not choose a best candidate operator. You might need to add
explicit type casts.
```

This happens because the system cannot decide which of the several possible ~ operators should be preferred. We can help it out with an explicit cast:

```
SELECT ~ CAST('20' AS int8) AS "negation";

 negation
----------
      -21
(1 row)
```

Example 10-4. Array Inclusion Operator Type Resolution

Here is another example of resolving an operator with one known and one unknown input:

```
SELECT array[1,2] <@ '{1,2,3}' as "is subset";

 is subset
-----------
 t
(1 row)
```

The PostgreSQL operator catalog has several entries for the infix operator `<@`, but the only two that could possibly accept an integer array on the left-hand side are array inclusion (`anyarray <@ anyarray`) and range inclusion (`anyelement <@ anyrange`). Since none of these polymorphic pseudo-types (see Section 8.20) are considered preferred, the parser cannot resolve the ambiguity on that basis. However, step 3.f tells it to assume that the unknown-type literal is of the same type as the other input, that is, integer array. Now only one of the two operators can match, so array inclusion is selected. (Had range inclusion been selected, we would have gotten an error, because the string does not have the right format to be a range literal.)

Example 10-5. Custom Operator on a Domain Type

Users sometimes try to declare operators applying just to a domain type. This is possible but is not nearly as useful as it might seem, because the operator resolution rules are designed to select operators applying to the domain's base type. As an example consider

```
CREATE DOMAIN mytext AS text CHECK(...);
```

```
CREATE FUNCTION mytext_eq_text (mytext, text) RETURNS boolean AS ...;
CREATE OPERATOR = (procedure=mytext_eq_text, leftarg=mytext, rightarg=text);
CREATE TABLE mytable (val mytext);

SELECT * FROM mytable WHERE val = 'foo';
```

This query will not use the custom operator. The parser will first see if there is a `mytext = mytext` operator (step 2.a), which there is not; then it will consider the domain's base type `text`, and see if there is a `text = text` operator (step 2.b), which there is; so it resolves the `unknown`-type literal as `text` and uses the `text = text` operator. The only way to get the custom operator to be used is to explicitly cast the literal:

```
SELECT * FROM mytable WHERE val = text 'foo';
```

so that the `mytext = text` operator is found immediately according to the exact-match rule. If the best-match rules are reached, they actively discriminate against operators on domain types. If they did not, such an operator would create too many ambiguous-operator failures, because the casting rules always consider a domain as castable to or from its base type, and so the domain operator would be considered usable in all the same cases as a similarly-named operator on the base type.

10.3. Functions

The specific function that is referenced by a function call is determined using the following procedure.

Function Type Resolution

1. Select the functions to be considered from the `pg_proc` system catalog. If a non-schema-qualified function name was used, the functions considered are those with the matching name and argument count that are visible in the current search path (see Section 5.7.3). If a qualified function name was given, only functions in the specified schema are considered.

    a. If the search path finds multiple functions of identical argument types, only the one appearing earliest in the path is considered. Functions of different argument types are considered on an equal footing regardless of search path position.

    b. If a function is declared with a `VARIADIC` array parameter, and the call does not use the `VARIADIC` keyword, then the function is treated as if the array parameter were replaced by one or more occurrences of its element type, as needed to match the call. After such expansion the function might have effective argument types identical to some non-variadic function. In that case the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

    c. Functions that have default values for parameters are considered to match any call that omits zero or more of the defaultable parameter positions. If more than one such function matches a call, the one appearing earliest in the search path is used. If there are two or more such functions in the same schema with identical parameter types in the non-defaulted positions (which is possible if they have different sets of defaultable parameters), the system will not be able to determine which to prefer, and so an "ambiguous function call" error will result if no better match to the call can be found.

2. Check for a function accepting exactly the input argument types. If one exists (there can be only one exact match in the set of functions considered), use it. (Cases involving `unknown` will never find a match at this step.)

3. If no exact match is found, see if the function call appears to be a special type conversion request. This happens if the function call has just one argument and the function name is the same as the (internal) name of some data type. Furthermore, the function argument must be either an unknown-type literal, or a type that is binary-coercible to the named data type, or a type that could be converted to the named data type by applying that type's I/O functions (that is, the conversion is either to or from one of the standard string types). When these conditions are met, the function call is treated as a form of `CAST` specification. [1]

4. Look for the best match.

    a. Discard candidate functions for which the input types do not match and cannot be converted (using an implicit conversion) to match. `unknown` literals are assumed to be convertible to anything for this purpose. If only one candidate remains, use it; else continue to the next step.

    b. If any input argument is of a domain type, treat it as being of the domain's base type for all subsequent steps. This ensures that domains act like their base types for purposes of ambiguous-function resolution.

    c. Run through all candidates and keep those with the most exact matches on input types. Keep all candidates if none have exact matches. If only one candidate remains, use it; else continue to the next step.

    d. Run through all candidates and keep those that accept preferred types (of the input data type's type category) at the most positions where type conversion will be required. Keep all candidates if none accept preferred types. If only one candidate remains, use it; else continue to the next step.

    e. If any input arguments are `unknown`, check the type categories accepted at those argument positions by the remaining candidates. At each position, select the `string` category if any candidate accepts that category. (This bias towards string is appropriate since an unknown-type literal looks like a string.) Otherwise, if all the remaining candidates accept the same type category, select that category; otherwise fail because the correct choice cannot be deduced without more clues. Now discard candidates that do not accept the selected type category. Furthermore, if any candidate accepts a preferred type in that category, discard candidates that accept non-preferred types for that argument. Keep all candidates if none survive these tests. If only one candidate remains, use it; else continue to the next step.

    f. If there are both `unknown` and known-type arguments, and all the known-type arguments have the same type, assume that the `unknown` arguments are also of that type, and check which candidates can accept that type at the `unknown`-argument positions. If exactly one candidate passes this test, use it. Otherwise, fail.

Note that the "best match" rules are identical for operator and function type resolution. Some examples follow.

Example 10-6. Rounding Function Argument Type Resolution

There is only one `round` function that takes two arguments; it takes a first argument of type `numeric` and a second argument of type `integer`. So the following query automatically converts the first

1. The reason for this step is to support function-style cast specifications in cases where there is not an actual cast function. If there is a cast function, it is conventionally named after its output type, and so there is no need to have a special case. See CREATE CAST for additional commentary.

argument of type integer to numeric:

```
SELECT round(4, 4);

 round
--------
 4.0000
(1 row)
```

That query is actually transformed by the parser to:

```
SELECT round(CAST (4 AS numeric), 4);
```

Since numeric constants with decimal points are initially assigned the type numeric, the following query will require no type conversion and therefore might be slightly more efficient:

```
SELECT round(4.0, 4);
```

Example 10-7. Substring Function Type Resolution

There are several substr functions, one of which takes types text and integer. If called with a string constant of unspecified type, the system chooses the candidate function that accepts an argument of the preferred category string (namely of type text).

```
SELECT substr('1234', 3);

 substr
--------
     34
(1 row)
```

If the string is declared to be of type varchar, as might be the case if it comes from a table, then the parser will try to convert it to become text:

```
SELECT substr(varchar '1234', 3);

 substr
--------
     34
(1 row)
```

This is transformed by the parser to effectively become:

```
SELECT substr(CAST (varchar '1234' AS text), 3);
```

> **Note:** The parser learns from the pg_cast catalog that text and varchar are binary-compatible, meaning that one can be passed to a function that accepts the other without doing any physical conversion. Therefore, no type conversion call is really inserted in this case.

And, if the function is called with an argument of type integer, the parser will try to convert that to text:

```
SELECT substr(1234, 3);
ERROR:  function substr(integer, integer) does not exist
HINT:  No function matches the given name and argument types. You might need
to add explicit type casts.
```

This does not work because integer does not have an implicit cast to text. An explicit cast will work, however:

```
SELECT substr(CAST (1234 AS text), 3);

 substr
--------
     34
(1 row)
```

10.4. Value Storage

Values to be inserted into a table are converted to the destination column's data type according to the following steps.

Value Storage Type Conversion

1. Check for an exact match with the target.
2. Otherwise, try to convert the expression to the target type. This will succeed if there is a registered cast between the two types. If the expression is an unknown-type literal, the contents of the literal string will be fed to the input conversion routine for the target type.
3. Check to see if there is a sizing cast for the target type. A sizing cast is a cast from that type to itself. If one is found in the `pg_cast` catalog, apply it to the expression before storing into the destination column. The implementation function for such a cast always takes an extra parameter of type `integer`, which receives the destination column's `atttypmod` value (typically its declared length, although the interpretation of `atttypmod` varies for different data types), and it may take a third `boolean` parameter that says whether the cast is explicit or implicit. The cast function is responsible for applying any length-dependent semantics such as size checking or truncation.

Example 10-8. `character` Storage Type Conversion

For a target column declared as `character(20)` the following statement shows that the stored value is sized correctly:

```
CREATE TABLE vv (v character(20));
INSERT INTO vv SELECT 'abc' || 'def';
SELECT v, octet_length(v) FROM vv;

          v           | octet_length
----------------------+--------------
 abcdef               |           20
(1 row)
```

What has really happened here is that the two unknown literals are resolved to `text` by default, allowing the `||` operator to be resolved as `text` concatenation. Then the `text` result of the operator is converted to `bpchar` ("blank-padded char", the internal name of the `character` data type) to match the target column type. (Since the conversion from `text` to `bpchar` is binary-coercible, this conversion does not insert any real function call.) Finally, the sizing function `bpchar(bpchar, integer, boolean)` is found in the system catalog and applied to the operator's result and the stored column length. This type-specific function performs the required length check and addition of padding spaces.

10.5. UNION, CASE, and Related Constructs

SQL UNION constructs must match up possibly dissimilar types to become a single result set. The resolution algorithm is applied separately to each output column of a union query. The INTERSECT and EXCEPT constructs resolve dissimilar types in the same way as UNION. The CASE, ARRAY, VALUES, GREATEST and LEAST constructs use the identical algorithm to match up their component expressions and select a result data type.

Type Resolution for UNION, CASE, and Related Constructs

1. If all inputs are of the same type, and it is not unknown, resolve as that type.
2. If any input is of a domain type, treat it as being of the domain's base type for all subsequent steps. [2]
3. If all inputs are of type unknown, resolve as type text (the preferred type of the string category). Otherwise, unknown inputs are ignored.
4. If the non-unknown inputs are not all of the same type category, fail.
5. Choose the first non-unknown input type which is a preferred type in that category, if there is one.
6. Otherwise, choose the last non-unknown input type that allows all the preceding non-unknown inputs to be implicitly converted to it. (There always is such a type, since at least the first type in the list must satisfy this condition.)
7. Convert all inputs to the selected type. Fail if there is not a conversion from a given input to the selected type.

Some examples follow.

Example 10-9. Type Resolution with Underspecified Types in a Union

```
SELECT text 'a' AS "text" UNION SELECT 'b';

 text
------
 a
 b
(2 rows)
```

Here, the unknown-type literal 'b' will be resolved to type text.

Example 10-10. Type Resolution in a Simple Union

```
SELECT 1.2 AS "numeric" UNION SELECT 1;

 numeric
---------
       1
     1.2
```

2. Somewhat like the treatment of domain inputs for operators and functions, this behavior allows a domain type to be preserved through a UNION or similar construct, so long as the user is careful to ensure that all inputs are implicitly or explicitly of that exact type. Otherwise the domain's base type will be preferred.

```
(2 rows)
```

The literal `1.2` is of type `numeric`, and the `integer` value `1` can be cast implicitly to `numeric`, so that type is used.

Example 10-11. Type Resolution in a Transposed Union

```
SELECT 1 AS "real" UNION SELECT CAST('2.2' AS REAL);

 real
------
    1
  2.2
(2 rows)
```

Here, since type `real` cannot be implicitly cast to `integer`, but `integer` can be implicitly cast to `real`, the union result type is resolved as `real`.

Chapter 11. Indexes

Indexes are a common way to enhance database performance. An index allows the database server to find and retrieve specific rows much faster than it could do without an index. But indexes also add overhead to the database system as a whole, so they should be used sensibly.

11.1. Introduction

Suppose we have a table similar to this:

```
CREATE TABLE test1 (
    id integer,
    content varchar
);
```

and the application issues many queries of the form:

```
SELECT content FROM test1 WHERE id = constant;
```

With no advance preparation, the system would have to scan the entire `test1` table, row by row, to find all matching entries. If there are many rows in `test1` and only a few rows (perhaps zero or one) that would be returned by such a query, this is clearly an inefficient method. But if the system has been instructed to maintain an index on the `id` column, it can use a more efficient method for locating matching rows. For instance, it might only have to walk a few levels deep into a search tree.

A similar approach is used in most non-fiction books: terms and concepts that are frequently looked up by readers are collected in an alphabetic index at the end of the book. The interested reader can scan the index relatively quickly and flip to the appropriate page(s), rather than having to read the entire book to find the material of interest. Just as it is the task of the author to anticipate the items that readers are likely to look up, it is the task of the database programmer to foresee which indexes will be useful.

The following command can be used to create an index on the `id` column, as discussed:

```
CREATE INDEX test1_id_index ON test1 (id);
```

The name `test1_id_index` can be chosen freely, but you should pick something that enables you to remember later what the index was for.

To remove an index, use the `DROP INDEX` command. Indexes can be added to and removed from tables at any time.

Once an index is created, no further intervention is required: the system will update the index when the table is modified, and it will use the index in queries when it thinks doing so would be more efficient than a sequential table scan. But you might have to run the `ANALYZE` command regularly to update statistics to allow the query planner to make educated decisions. See Chapter 14 for information about how to find out whether an index is used and when and why the planner might choose *not* to use an index.

Indexes can also benefit `UPDATE` and `DELETE` commands with search conditions. Indexes can moreover be used in join searches. Thus, an index defined on a column that is part of a join condition can also significantly speed up queries with joins.

Creating an index on a large table can take a long time. By default, PostgreSQL allows reads (`SELECT` statements) to occur on the table in parallel with index creation, but writes (`INSERT`,

UPDATE, DELETE) are blocked until the index build is finished. In production environments this is often unacceptable. It is possible to allow writes to occur in parallel with index creation, but there are several caveats to be aware of — for more information see *Building Indexes Concurrently*.

After an index is created, the system has to keep it synchronized with the table. This adds overhead to data manipulation operations. Therefore indexes that are seldom or never used in queries should be removed.

11.2. Index Types

PostgreSQL provides several index types: B-tree, Hash, GiST, SP-GiST and GIN. Each index type uses a different algorithm that is best suited to different types of queries. By default, the CREATE INDEX command creates B-tree indexes, which fit the most common situations.

B-trees can handle equality and range queries on data that can be sorted into some ordering. In particular, the PostgreSQL query planner will consider using a B-tree index whenever an indexed column is involved in a comparison using one of these operators:

```
<
<=
=
>=
>
```

Constructs equivalent to combinations of these operators, such as BETWEEN and IN, can also be implemented with a B-tree index search. Also, an IS NULL or IS NOT NULL condition on an index column can be used with a B-tree index.

The optimizer can also use a B-tree index for queries involving the pattern matching operators LIKE and ~ *if* the pattern is a constant and is anchored to the beginning of the string — for example, `col LIKE 'foo%'` or `col ~ '^foo'`, but not `col LIKE '%bar'`. However, if your database does not use the C locale you will need to create the index with a special operator class to support indexing of pattern-matching queries; see Section 11.9 below. It is also possible to use B-tree indexes for ILIKE and ~*, but only if the pattern starts with non-alphabetic characters, i.e., characters that are not affected by upper/lower case conversion.

B-tree indexes can also be used to retrieve data in sorted order. This is not always faster than a simple scan and sort, but it is often helpful.

Hash indexes can only handle simple equality comparisons. The query planner will consider using a hash index whenever an indexed column is involved in a comparison using the = operator. The following command is used to create a hash index:

```
CREATE INDEX name ON table USING hash (column);
```

> **Caution**
>
> Hash index operations are not presently WAL-logged, so hash indexes might need to be rebuilt with REINDEX after a database crash if there were unwritten changes. Also, changes to hash indexes are not replicated over streaming or file-based replication after the initial base backup, so they give wrong answers to queries that subsequently use them. For these reasons, hash index use is presently discouraged.

GiST indexes are not a single kind of index, but rather an infrastructure within which many different indexing strategies can be implemented. Accordingly, the particular operators with which a GiST index can be used vary depending on the indexing strategy (the *operator class*). As an example, the standard distribution of PostgreSQL includes GiST operator classes for several two-dimensional geometric data types, which support indexed queries using these operators:

```
<<
&<
&>
>>
<<|
&<|
|&>
|>>
@>
<@
~=
&&
```

(See Section 9.11 for the meaning of these operators.) The GiST operator classes included in the standard distribution are documented in Table 56-1. Many other GiST operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 56.

GiST indexes are also capable of optimizing "nearest-neighbor" searches, such as

```
SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT 10;
```

which finds the ten places closest to a given target point. The ability to do this is again dependent on the particular operator class being used. In Table 56-1, operators that can be used in this way are listed in the column "Ordering Operators".

SP-GiST indexes, like GiST indexes, offer an infrastructure that supports various kinds of searches. SP-GiST permits implementation of a wide range of different non-balanced disk-based data structures, such as quadtrees, k-d trees, and radix trees (tries). As an example, the standard distribution of PostgreSQL includes SP-GiST operator classes for two-dimensional points, which support indexed queries using these operators:

```
<<
>>
~=
<@
<^
>^
```

(See Section 9.11 for the meaning of these operators.) The SP-GiST operator classes included in the standard distribution are documented in Table 57-1. For more information see Chapter 57.

GIN indexes are inverted indexes which can handle values that contain more than one key, arrays for example. Like GiST and SP-GiST, GIN can support many different user-defined indexing strategies and the particular operators with which a GIN index can be used vary depending on the indexing strategy. As an example, the standard distribution of PostgreSQL includes GIN operator classes for one-dimensional arrays, which support indexed queries using these operators:

```
<@
@>
```

=

&&

(See Section 9.18 for the meaning of these operators.) The GIN operator classes included in the standard distribution are documented in Table 58-1. Many other GIN operator classes are available in the `contrib` collection or as separate projects. For more information see Chapter 58.

11.3. Multicolumn Indexes

An index can be defined on more than one column of a table. For example, if you have a table of this form:

```
CREATE TABLE test2 (
  major int,
  minor int,
  name varchar
);
```

(say, you keep your `/dev` directory in a database...) and you frequently issue queries like:

```
SELECT name FROM test2 WHERE major = constant AND minor = constant;
```

then it might be appropriate to define an index on the columns `major` and `minor` together, e.g.:

```
CREATE INDEX test2_mm_idx ON test2 (major, minor);
```

Currently, only the B-tree, GiST and GIN index types support multicolumn indexes. Up to 32 columns can be specified. (This limit can be altered when building PostgreSQL; see the file `pg_config_manual.h`.)

A multicolumn B-tree index can be used with query conditions that involve any subset of the index's columns, but the index is most efficient when there are constraints on the leading (leftmost) columns. The exact rule is that equality constraints on leading columns, plus any inequality constraints on the first column that does not have an equality constraint, will be used to limit the portion of the index that is scanned. Constraints on columns to the right of these columns are checked in the index, so they save visits to the table proper, but they do not reduce the portion of the index that has to be scanned. For example, given an index on `(a, b, c)` and a query condition `WHERE a = 5 AND b >= 42 AND c < 77`, the index would have to be scanned from the first entry with `a` = 5 and `b` = 42 up through the last entry with `a` = 5. Index entries with `c` >= 77 would be skipped, but they'd still have to be scanned through. This index could in principle be used for queries that have constraints on `b` and/or `c` with no constraint on `a` — but the entire index would have to be scanned, so in most cases the planner would prefer a sequential table scan over using the index.

A multicolumn GiST index can be used with query conditions that involve any subset of the index's columns. Conditions on additional columns restrict the entries returned by the index, but the condition on the first column is the most important one for determining how much of the index needs to be scanned. A GiST index will be relatively ineffective if its first column has only a few distinct values, even if there are many distinct values in additional columns.

A multicolumn GIN index can be used with query conditions that involve any subset of the index's columns. Unlike B-tree or GiST, index search effectiveness is the same regardless of which index column(s) the query conditions use.

Of course, each column must be used with operators appropriate to the index type; clauses that involve other operators will not be considered.

Multicolumn indexes should be used sparingly. In most situations, an index on a single column is sufficient and saves space and time. Indexes with more than three columns are unlikely to be helpful unless the usage of the table is extremely stylized. See also Section 11.5 for some discussion of the merits of different index configurations.

11.4. Indexes and ORDER BY

In addition to simply finding the rows to be returned by a query, an index may be able to deliver them in a specific sorted order. This allows a query's ORDER BY specification to be honored without a separate sorting step. Of the index types currently supported by PostgreSQL, only B-tree can produce sorted output — the other index types return matching rows in an unspecified, implementation-dependent order.

The planner will consider satisfying an ORDER BY specification either by scanning an available index that matches the specification, or by scanning the table in physical order and doing an explicit sort. For a query that requires scanning a large fraction of the table, an explicit sort is likely to be faster than using an index because it requires less disk I/O due to following a sequential access pattern. Indexes are more useful when only a few rows need be fetched. An important special case is ORDER BY in combination with LIMIT *n*: an explicit sort will have to process all the data to identify the first *n* rows, but if there is an index matching the ORDER BY, the first *n* rows can be retrieved directly, without scanning the remainder at all.

By default, B-tree indexes store their entries in ascending order with nulls last. This means that a forward scan of an index on column x produces output satisfying ORDER BY x (or more verbosely, ORDER BY x ASC NULLS LAST). The index can also be scanned backward, producing output satisfying ORDER BY x DESC (or more verbosely, ORDER BY x DESC NULLS FIRST, since NULLS FIRST is the default for ORDER BY DESC).

You can adjust the ordering of a B-tree index by including the options ASC, DESC, NULLS FIRST, and/or NULLS LAST when creating the index; for example:

```
CREATE INDEX test2_info_nulls_low ON test2 (info NULLS FIRST);
CREATE INDEX test3_desc_index ON test3 (id DESC NULLS LAST);
```

An index stored in ascending order with nulls first can satisfy either ORDER BY x ASC NULLS FIRST or ORDER BY x DESC NULLS LAST depending on which direction it is scanned in.

You might wonder why bother providing all four options, when two options together with the possibility of backward scan would cover all the variants of ORDER BY. In single-column indexes the options are indeed redundant, but in multicolumn indexes they can be useful. Consider a two-column index on (x, y): this can satisfy ORDER BY x, y if we scan forward, or ORDER BY x DESC, y DESC if we scan backward. But it might be that the application frequently needs to use ORDER BY x ASC, y DESC. There is no way to get that ordering from a plain index, but it is possible if the index is defined as (x ASC, y DESC) or (x DESC, y ASC).

Obviously, indexes with non-default sort orderings are a fairly specialized feature, but sometimes they can produce tremendous speedups for certain queries. Whether it's worth maintaining such an index depends on how often you use queries that require a special sort ordering.

11.5. Combining Multiple Indexes

A single index scan can only use query clauses that use the index's columns with operators of its operator class and are joined with `AND`. For example, given an index on `(a, b)` a query condition like `WHERE a = 5 AND b = 6` could use the index, but a query like `WHERE a = 5 OR b = 6` could not directly use the index.

Fortunately, PostgreSQL has the ability to combine multiple indexes (including multiple uses of the same index) to handle cases that cannot be implemented by single index scans. The system can form `AND` and `OR` conditions across several index scans. For example, a query like `WHERE x = 42 OR x = 47 OR x = 53 OR x = 99` could be broken down into four separate scans of an index on `x`, each scan using one of the query clauses. The results of these scans are then ORed together to produce the result. Another example is that if we have separate indexes on `x` and `y`, one possible implementation of a query like `WHERE x = 5 AND y = 6` is to use each index with the appropriate query clause and then AND together the index results to identify the result rows.

To combine multiple indexes, the system scans each needed index and prepares a *bitmap* in memory giving the locations of table rows that are reported as matching that index's conditions. The bitmaps are then ANDed and ORed together as needed by the query. Finally, the actual table rows are visited and returned. The table rows are visited in physical order, because that is how the bitmap is laid out; this means that any ordering of the original indexes is lost, and so a separate sort step will be needed if the query has an `ORDER BY` clause. For this reason, and because each additional index scan adds extra time, the planner will sometimes choose to use a simple index scan even though additional indexes are available that could have been used as well.

In all but the simplest applications, there are various combinations of indexes that might be useful, and the database developer must make trade-offs to decide which indexes to provide. Sometimes multicolumn indexes are best, but sometimes it's better to create separate indexes and rely on the index-combination feature. For example, if your workload includes a mix of queries that sometimes involve only column `x`, sometimes only column `y`, and sometimes both columns, you might choose to create two separate indexes on `x` and `y`, relying on index combination to process the queries that use both columns. You could also create a multicolumn index on `(x, y)`. This index would typically be more efficient than index combination for queries involving both columns, but as discussed in Section 11.3, it would be almost useless for queries involving only `y`, so it should not be the only index. A combination of the multicolumn index and a separate index on `y` would serve reasonably well. For queries involving only `x`, the multicolumn index could be used, though it would be larger and hence slower than an index on `x` alone. The last alternative is to create all three indexes, but this is probably only reasonable if the table is searched much more often than it is updated and all three types of query are common. If one of the types of query is much less common than the others, you'd probably settle for creating just the two indexes that best match the common types.

11.6. Unique Indexes

Indexes can also be used to enforce uniqueness of a column's value, or the uniqueness of the combined values of more than one column.

```
CREATE UNIQUE INDEX name ON table (column [, ...]);
```

Currently, only B-tree indexes can be declared unique.

When an index is declared unique, multiple table rows with equal indexed values are not allowed. Null values are not considered equal. A multicolumn unique index will only reject cases where all indexed columns are equal in multiple rows.

PostgreSQL automatically creates a unique index when a unique constraint or primary key is defined for a table. The index covers the columns that make up the primary key or unique constraint (a multicolumn index, if appropriate), and is the mechanism that enforces the constraint.

> **Note:** The preferred way to add a unique constraint to a table is `ALTER TABLE ... ADD CONSTRAINT`. The use of indexes to enforce unique constraints could be considered an implementation detail that should not be accessed directly. One should, however, be aware that there's no need to manually create indexes on unique columns; doing so would just duplicate the automatically-created index.

11.7. Indexes on Expressions

An index column need not be just a column of the underlying table, but can be a function or scalar expression computed from one or more columns of the table. This feature is useful to obtain fast access to tables based on the results of computations.

For example, a common way to do case-insensitive comparisons is to use the `lower` function:

```
SELECT * FROM test1 WHERE lower(col1) = 'value';
```

This query can use an index if one has been defined on the result of the `lower(col1)` function:

```
CREATE INDEX test1_lower_col1_idx ON test1 (lower(col1));
```

If we were to declare this index `UNIQUE`, it would prevent creation of rows whose `col1` values differ only in case, as well as rows whose `col1` values are actually identical. Thus, indexes on expressions can be used to enforce constraints that are not definable as simple unique constraints.

As another example, if one often does queries like:

```
SELECT * FROM people WHERE (first_name || ' ' || last_name) = 'John Smith';
```

then it might be worth creating an index like this:

```
CREATE INDEX people_names ON people ((first_name || ' ' || last_name));
```

The syntax of the `CREATE INDEX` command normally requires writing parentheses around index expressions, as shown in the second example. The parentheses can be omitted when the expression is just a function call, as in the first example.

Index expressions are relatively expensive to maintain, because the derived expression(s) must be computed for each row upon insertion and whenever it is updated. However, the index expressions are *not* recomputed during an indexed search, since they are already stored in the index. In both examples above, the system sees the query as just `WHERE indexedcolumn = 'constant'` and so the speed of the search is equivalent to any other simple index query. Thus, indexes on expressions are useful when retrieval speed is more important than insertion and update speed.

11.8. Partial Indexes

A *partial index* is an index built over a subset of a table; the subset is defined by a conditional expression (called the *predicate* of the partial index). The index contains entries only for those table rows that satisfy the predicate. Partial indexes are a specialized feature, but there are several situations in which they are useful.

One major reason for using a partial index is to avoid indexing common values. Since a query searching for a common value (one that accounts for more than a few percent of all the table rows) will not use the index anyway, there is no point in keeping those rows in the index at all. This reduces the size of the index, which will speed up those queries that do use the index. It will also speed up many table update operations because the index does not need to be updated in all cases. Example 11-1 shows a possible application of this idea.

Example 11-1. Setting up a Partial Index to Exclude Common Values

Suppose you are storing web server access logs in a database. Most accesses originate from the IP address range of your organization but some are from elsewhere (say, employees on dial-up connections). If your searches by IP are primarily for outside accesses, you probably do not need to index the IP range that corresponds to your organization's subnet.

Assume a table like this:

```
CREATE TABLE access_log (
    url varchar,
    client_ip inet,
    ...
);
```

To create a partial index that suits our example, use a command such as this:

```
CREATE INDEX access_log_client_ip_ix ON access_log (client_ip)
WHERE NOT (client_ip > inet '192.168.100.0' AND
           client_ip < inet '192.168.100.255');
```

A typical query that can use this index would be:

```
SELECT *
FROM access_log
WHERE url = '/index.html' AND client_ip = inet '212.78.10.32';
```

A query that cannot use this index is:

```
SELECT *
FROM access_log
WHERE client_ip = inet '192.168.100.23';
```

Observe that this kind of partial index requires that the common values be predetermined, so such partial indexes are best used for data distributions that do not change. The indexes can be recreated occasionally to adjust for new data distributions, but this adds maintenance effort.

Another possible use for a partial index is to exclude values from the index that the typical query workload is not interested in; this is shown in Example 11-2. This results in the same advantages as listed above, but it prevents the "uninteresting" values from being accessed via that index, even if an index scan might be profitable in that case. Obviously, setting up partial indexes for this kind of scenario will require a lot of care and experimentation.

Example 11-2. Setting up a Partial Index to Exclude Uninteresting Values

If you have a table that contains both billed and unbilled orders, where the unbilled orders take up a small fraction of the total table and yet those are the most-accessed rows, you can improve performance by creating an index on just the unbilled rows. The command to create the index would look like this:

```
CREATE INDEX orders_unbilled_index ON orders (order_nr)
    WHERE billed is not true;
```

A possible query to use this index would be:

```
SELECT * FROM orders WHERE billed is not true AND order_nr < 10000;
```

However, the index can also be used in queries that do not involve `order_nr` at all, e.g.:

```
SELECT * FROM orders WHERE billed is not true AND amount > 5000.00;
```

This is not as efficient as a partial index on the `amount` column would be, since the system has to scan the entire index. Yet, if there are relatively few unbilled orders, using this partial index just to find the unbilled orders could be a win.

Note that this query cannot use this index:

```
SELECT * FROM orders WHERE order_nr = 3501;
```

The order 3501 might be among the billed or unbilled orders.

Example 11-2 also illustrates that the indexed column and the column used in the predicate do not need to match. PostgreSQL supports partial indexes with arbitrary predicates, so long as only columns of the table being indexed are involved. However, keep in mind that the predicate must match the conditions used in the queries that are supposed to benefit from the index. To be precise, a partial index can be used in a query only if the system can recognize that the `WHERE` condition of the query mathematically implies the predicate of the index. PostgreSQL does not have a sophisticated theorem prover that can recognize mathematically equivalent expressions that are written in different forms. (Not only is such a general theorem prover extremely difficult to create, it would probably be too slow to be of any real use.) The system can recognize simple inequality implications, for example "x < 1" implies "x < 2"; otherwise the predicate condition must exactly match part of the query's `WHERE` condition or the index will not be recognized as usable. Matching takes place at query planning time, not at run time. As a result, parameterized query clauses do not work with a partial index. For example a prepared query with a parameter might specify "x < ?" which will never imply "x < 2" for all possible values of the parameter.

A third possible use for partial indexes does not require the index to be used in queries at all. The idea here is to create a unique index over a subset of a table, as in Example 11-3. This enforces uniqueness among the rows that satisfy the index predicate, without constraining those that do not.

Example 11-3. Setting up a Partial Unique Index

Suppose that we have a table describing test outcomes. We wish to ensure that there is only one "successful" entry for a given subject and target combination, but there might be any number of "unsuccessful" entries. Here is one way to do it:

```
CREATE TABLE tests (
    subject text,
    target text,
    success boolean,
    ...
);
```

```
CREATE UNIQUE INDEX tests_success_constraint ON tests (subject, target)
    WHERE success;
```

This is a particularly efficient approach when there are few successful tests and many unsuccessful ones.

Finally, a partial index can also be used to override the system's query plan choices. Also, data sets with peculiar distributions might cause the system to use an index when it really should not. In that case the index can be set up so that it is not available for the offending query. Normally, PostgreSQL makes reasonable choices about index usage (e.g., it avoids them when retrieving common values, so the earlier example really only saves index size, it is not required to avoid index usage), and grossly incorrect plan choices are cause for a bug report.

Keep in mind that setting up a partial index indicates that you know at least as much as the query planner knows, in particular you know when an index might be profitable. Forming this knowledge requires experience and understanding of how indexes in PostgreSQL work. In most cases, the advantage of a partial index over a regular index will be minimal.

More information about partial indexes can be found in *The case for partial indexes* , *Partial indexing in POSTGRES: research project*, and *Generalized Partial Indexes (cached version)* .

11.9. Operator Classes and Operator Families

An index definition can specify an *operator class* for each column of an index.

```
CREATE INDEX name ON table (column opclass [sort options] [, ...]);
```

The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on the type `int4` would use the `int4_ops` class; this operator class includes comparison functions for values of type `int4`. In practice the default operator class for the column's data type is usually sufficient. The main reason for having operator classes is that for some data types, there could be more than one meaningful index behavior. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when making an index. The operator class determines the basic sort ordering (which can then be modified by adding sort options `COLLATE`, `ASC`/`DESC` and/or `NULLS FIRST`/`NULLS LAST`).

There are also some built-in operator classes besides the default ones:

- The operator classes `text_pattern_ops`, `varchar_pattern_ops`, and `bpchar_pattern_ops` support B-tree indexes on the types `text`, `varchar`, and `char` respectively. The difference from the default operator classes is that the values are compared strictly character by character rather than according to the locale-specific collation rules. This makes these operator classes suitable for use by queries involving pattern matching expressions (`LIKE` or POSIX regular expressions) when the database does not use the standard "C" locale. As an example, you might index a `varchar` column like this:

  ```
  CREATE INDEX test_index ON test_table (col varchar_pattern_ops);
  ```

  Note that you should also create an index with the default operator class if you want queries involving ordinary <, <=, >, or >= comparisons to use an index. Such queries cannot use the *xxx*`_pattern_ops` operator classes. (Ordinary equality comparisons can use these operator classes, however.) It is possible to create multiple indexes on the same column with different operator classes. If you do use the C locale, you do not need the *xxx*`_pattern_ops` operator

classes, because an index with the default operator class is usable for pattern-matching queries in the C locale.

The following query shows all defined operator classes:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
    FROM pg_am am, pg_opclass opc
    WHERE opc.opcmethod = am.oid
    ORDER BY index_method, opclass_name;
```

An operator class is actually just a subset of a larger structure called an *operator family*. In cases where several data types have similar behaviors, it is frequently useful to define cross-data-type operators and allow these to work with indexes. To do this, the operator classes for each of the types must be grouped into the same operator family. The cross-type operators are members of the family, but are not associated with any single class within the family.

This expanded version of the previous query shows the operator family each operator class belongs to:

```
SELECT am.amname AS index_method,
       opc.opcname AS opclass_name,
       opf.opfname AS opfamily_name,
       opc.opcintype::regtype AS indexed_type,
       opc.opcdefault AS is_default
    FROM pg_am am, pg_opclass opc, pg_opfamily opf
    WHERE opc.opcmethod = am.oid AND
          opc.opcfamily = opf.oid
    ORDER BY index_method, opclass_name;
```

This query shows all defined operator families and all the operators included in each family:

```
SELECT am.amname AS index_method,
       opf.opfname AS opfamily_name,
       amop.amopopr::regoperator AS opfamily_operator
    FROM pg_am am, pg_opfamily opf, pg_amop amop
    WHERE opf.opfmethod = am.oid AND
          amop.amopfamily = opf.oid
    ORDER BY index_method, opfamily_name, opfamily_operator;
```

11.10. Indexes and Collations

An index can support only one collation per index column. If multiple collations are of interest, multiple indexes may be needed.

Consider these statements:

```
CREATE TABLE test1c (
```

```
    id integer,
    content varchar COLLATE "x"
);

CREATE INDEX test1c_content_index ON test1c (content);
```

The index automatically uses the collation of the underlying column. So a query of the form

```
SELECT * FROM test1c WHERE content > constant;
```

could use the index, because the comparison will by default use the collation of the column. However, this index cannot accelerate queries that involve some other collation. So if queries of the form, say,

```
SELECT * FROM test1c WHERE content > constant COLLATE "y";
```

are also of interest, an additional index could be created that supports the `"y"` collation, like this:

```
CREATE INDEX test1c_content_y_index ON test1c (content COLLATE "y");
```

11.11. Examining Index Usage

Although indexes in PostgreSQL do not need maintenance or tuning, it is still important to check which indexes are actually used by the real-life query workload. Examining index usage for an individual query is done with the EXPLAIN command; its application for this purpose is illustrated in Section 14.1. It is also possible to gather overall statistics about index usage in a running server, as described in Section 27.2.

It is difficult to formulate a general procedure for determining which indexes to create. There are a number of typical cases that have been shown in the examples throughout the previous sections. A good deal of experimentation is often necessary. The rest of this section gives some tips for that:

- Always run ANALYZE first. This command collects statistics about the distribution of the values in the table. This information is required to estimate the number of rows returned by a query, which is needed by the planner to assign realistic costs to each possible query plan. In absence of any real statistics, some default values are assumed, which are almost certain to be inaccurate. Examining an application's index usage without having run `ANALYZE` is therefore a lost cause. See Section 23.1.3 and Section 23.1.6 for more information.
- Use real data for experimentation. Using test data for setting up indexes will tell you what indexes you need for the test data, but that is all.

  It is especially fatal to use very small test data sets. While selecting 1000 out of 100000 rows could be a candidate for an index, selecting 1 out of 100 rows will hardly be, because the 100 rows probably fit within a single disk page, and there is no plan that can beat sequentially fetching 1 disk page.

  Also be careful when making up test data, which is often unavoidable when the application is not yet in production. Values that are very similar, completely random, or inserted in sorted order will skew the statistics away from the distribution that real data would have.
- When indexes are not used, it can be useful for testing to force their use. There are run-time parameters that can turn off various plan types (see Section 18.7.1). For instance, turning off sequential scans (`enable_seqscan`) and nested-loop joins (`enable_nestloop`), which are the most basic

plans, will force the system to use a different plan. If the system still chooses a sequential scan or nested-loop join then there is probably a more fundamental reason why the index is not being used; for example, the query condition does not match the index. (What kind of query can use what kind of index is explained in the previous sections.)

- If forcing index usage does use the index, then there are two possibilities: Either the system is right and using the index is indeed not appropriate, or the cost estimates of the query plans are not reflecting reality. So you should time your query with and without indexes. The `EXPLAIN ANALYZE` command can be useful here.
- If it turns out that the cost estimates are wrong, there are, again, two possibilities. The total cost is computed from the per-row costs of each plan node times the selectivity estimate of the plan node. The costs estimated for the plan nodes can be adjusted via run-time parameters (described in Section 18.7.2). An inaccurate selectivity estimate is due to insufficient statistics. It might be possible to improve this by tuning the statistics-gathering parameters (see ALTER TABLE).

  If you do not succeed in adjusting the costs to be more appropriate, then you might have to resort to forcing index usage explicitly. You might also want to contact the PostgreSQL developers to examine the issue.

Chapter 12. Full Text Search

12.1. Introduction

Full Text Searching (or just *text search*) provides the capability to identify natural-language *documents* that satisfy a *query*, and optionally to sort them by relevance to the query. The most common type of search is to find all documents containing given *query terms* and return them in order of their *similarity* to the query. Notions of `query` and `similarity` are very flexible and depend on the specific application. The simplest search considers `query` as a set of words and `similarity` as the frequency of query words in the document.

Textual search operators have existed in databases for years. PostgreSQL has `~`, `~*`, `LIKE`, and `ILIKE` operators for textual data types, but they lack many essential properties required by modern information systems:

- There is no linguistic support, even for English. Regular expressions are not sufficient because they cannot easily handle derived words, e.g., `satisfies` and `satisfy`. You might miss documents that contain `satisfies`, although you probably would like to find them when searching for `satisfy`. It is possible to use `OR` to search for multiple derived forms, but this is tedious and error-prone (some words can have several thousand derivatives).
- They provide no ordering (ranking) of search results, which makes them ineffective when thousands of matching documents are found.
- They tend to be slow because there is no index support, so they must process all documents for every search.

Full text indexing allows documents to be *preprocessed* and an index saved for later rapid searching. Preprocessing includes:

Parsing documents into tokens. It is useful to identify various classes of tokens, e.g., numbers, words, complex words, email addresses, so that they can be processed differently. In principle token classes depend on the specific application, but for most purposes it is adequate to use a predefined set of classes. PostgreSQL uses a *parser* to perform this step. A standard parser is provided, and custom parsers can be created for specific needs.

Converting tokens into lexemes. A lexeme is a string, just like a token, but it has been *normalized* so that different forms of the same word are made alike. For example, normalization almost always includes folding upper-case letters to lower-case, and often involves removal of suffixes (such as `s` or `es` in English). This allows searches to find variant forms of the same word, without tediously entering all the possible variants. Also, this step typically eliminates *stop words*, which are words that are so common that they are useless for searching. (In short, then, tokens are raw fragments of the document text, while lexemes are words that are believed useful for indexing and searching.) PostgreSQL uses *dictionaries* to perform this step. Various standard dictionaries are provided, and custom ones can be created for specific needs.

Storing preprocessed documents optimized for searching. For example, each document can be represented as a sorted array of normalized lexemes. Along with the lexemes it is often desirable to store positional information to use for *proximity ranking*, so that a document that contains a more "dense" region of query words is assigned a higher rank than one with scattered query words.

Dictionaries allow fine-grained control over how tokens are normalized. With appropriate dictionaries, you can:

- Define stop words that should not be indexed.
- Map synonyms to a single word using Ispell.
- Map phrases to a single word using a thesaurus.
- Map different variations of a word to a canonical form using an Ispell dictionary.
- Map different variations of a word to a canonical form using Snowball stemmer rules.

A data type `tsvector` is provided for storing preprocessed documents, along with a type `tsquery` for representing processed queries (Section 8.11). There are many functions and operators available for these data types (Section 9.13), the most important of which is the match operator `@@`, which we introduce in Section 12.1.2. Full text searches can be accelerated using indexes (Section 12.9).

12.1.1. What Is a Document?

A *document* is the unit of searching in a full text search system; for example, a magazine article or email message. The text search engine must be able to parse documents and store associations of lexemes (key words) with their parent document. Later, these associations are used to search for documents that contain query words.

For searches within PostgreSQL, a document is normally a textual field within a row of a database table, or possibly a combination (concatenation) of such fields, perhaps stored in several tables or obtained dynamically. In other words, a document can be constructed from different parts for indexing and it might not be stored anywhere as a whole. For example:

```
SELECT title || ' ' ||  author || ' ' ||  abstract || ' ' || body AS document
FROM messages
WHERE mid = 12;

SELECT m.title || ' ' || m.author || ' ' || m.abstract || ' ' || d.body AS document
FROM messages m, docs d
WHERE mid = did AND mid = 12;
```

> **Note:** Actually, in these example queries, `coalesce` should be used to prevent a single `NULL` attribute from causing a `NULL` result for the whole document.

Another possibility is to store the documents as simple text files in the file system. In this case, the database can be used to store the full text index and to execute searches, and some unique identifier can be used to retrieve the document from the file system. However, retrieving files from outside the database requires superuser permissions or special function support, so this is usually less convenient than keeping all the data inside PostgreSQL. Also, keeping everything inside the database allows easy access to document metadata to assist in indexing and display.

For text search purposes, each document must be reduced to the preprocessed `tsvector` format. Searching and ranking are performed entirely on the `tsvector` representation of a document — the original text need only be retrieved when the document has been selected for display to a user. We therefore often speak of the `tsvector` as being the document, but of course it is only a compact representation of the full document.

12.1.2. Basic Text Matching

Full text searching in PostgreSQL is based on the match operator `@@`, which returns `true` if a `tsvector` (document) matches a `tsquery` (query). It doesn't matter which data type is written first:

```
SELECT 'a fat cat sat on a mat and ate a fat rat'::tsvector @@ 'cat & rat'::tsquery;
 ?column?
----------
 t

SELECT 'fat & cow'::tsquery @@ 'a fat cat sat on a mat and ate a fat rat'::tsvector;
 ?column?
----------
 f
```

As the above example suggests, a `tsquery` is not just raw text, any more than a `tsvector` is. A `tsquery` contains search terms, which must be already-normalized lexemes, and may combine multiple terms using AND, OR, and NOT operators. (For details see Section 8.11.) There are functions `to_tsquery` and `plainto_tsquery` that are helpful in converting user-written text into a proper `tsquery`, for example by normalizing words appearing in the text. Similarly, `to_tsvector` is used to parse and normalize a document string. So in practice a text search match would look more like this:

```
SELECT to_tsvector('fat cats ate fat rats') @@ to_tsquery('fat & rat');
 ?column?
----------
 t
```

Observe that this match would not succeed if written as

```
SELECT 'fat cats ate fat rats'::tsvector @@ to_tsquery('fat & rat');
 ?column?
----------
 f
```

since here no normalization of the word `rats` will occur. The elements of a `tsvector` are lexemes, which are assumed already normalized, so `rats` does not match `rat`.

The `@@` operator also supports `text` input, allowing explicit conversion of a text string to `tsvector` or `tsquery` to be skipped in simple cases. The variants available are:

```
tsvector @@ tsquery
tsquery  @@ tsvector
text @@ tsquery
text @@ text
```

The first two of these we saw already. The form `text @@ tsquery` is equivalent to `to_tsvector(x) @@ y`. The form `text @@ text` is equivalent to `to_tsvector(x) @@ plainto_tsquery(y)`.

12.1.3. Configurations

The above are all simple text search examples. As mentioned before, full text search functionality includes the ability to do many more things: skip indexing certain words (stop words), process synonyms, and use sophisticated parsing, e.g., parse based on more than just white space. This functionality is controlled by *text search configurations*. PostgreSQL comes with predefined configurations for many languages, and you can easily create your own configurations. (psql's `\dF` command shows all available configurations.)

During installation an appropriate configuration is selected and default_text_search_config is set accordingly in `postgresql.conf`. If you are using the same text search configuration for the entire cluster you can use the value in `postgresql.conf`. To use different configurations throughout the cluster but the same configuration within any one database, use `ALTER DATABASE ... SET`. Otherwise, you can set `default_text_search_config` in each session.

Each text search function that depends on a configuration has an optional `regconfig` argument, so that the configuration to use can be specified explicitly. `default_text_search_config` is used only when this argument is omitted.

To make it easier to build custom text search configurations, a configuration is built up from simpler database objects. PostgreSQL's text search facility provides four types of configuration-related database objects:

- *Text search parsers* break documents into tokens and classify each token (for example, as words or numbers).
- *Text search dictionaries* convert tokens to normalized form and reject stop words.
- *Text search templates* provide the functions underlying dictionaries. (A dictionary simply specifies a template and a set of parameters for the template.)
- *Text search configurations* select a parser and a set of dictionaries to use to normalize the tokens produced by the parser.

Text search parsers and templates are built from low-level C functions; therefore it requires C programming ability to develop new ones, and superuser privileges to install one into a database. (There are examples of add-on parsers and templates in the `contrib/` area of the PostgreSQL distribution.) Since dictionaries and configurations just parameterize and connect together some underlying parsers and templates, no special privilege is needed to create a new dictionary or configuration. Examples of creating custom dictionaries and configurations appear later in this chapter.

12.2. Tables and Indexes

The examples in the previous section illustrated full text matching using simple constant strings. This section shows how to search table data, optionally using indexes.

12.2.1. Searching a Table

It is possible to do a full text search without an index. A simple query to print the `title` of each row that contains the word `friend` in its `body` field is:

```
SELECT title
FROM pgweb
WHERE to_tsvector('english', body) @@ to_tsquery('english', 'friend');
```

This will also find related words such as friends and friendly, since all these are reduced to the same normalized lexeme.

The query above specifies that the english configuration is to be used to parse and normalize the strings. Alternatively we could omit the configuration parameters:

```
SELECT title
FROM pgweb
WHERE to_tsvector(body) @@ to_tsquery('friend');
```

This query will use the configuration set by default_text_search_config.

A more complex example is to select the ten most recent documents that contain create and table in the title or body:

```
SELECT title
FROM pgweb
WHERE to_tsvector(title || ' ' || body) @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

For clarity we omitted the coalesce function calls which would be needed to find rows that contain NULL in one of the two fields.

Although these queries will work without an index, most applications will find this approach too slow, except perhaps for occasional ad-hoc searches. Practical use of text searching usually requires creating an index.

12.2.2. Creating Indexes

We can create a GIN index (Section 12.9) to speed up text searches:

```
CREATE INDEX pgweb_idx ON pgweb USING gin(to_tsvector('english', body));
```

Notice that the 2-argument version of to_tsvector is used. Only text search functions that specify a configuration name can be used in expression indexes (Section 11.7). This is because the index contents must be unaffected by default_text_search_config. If they were affected, the index contents might be inconsistent because different entries could contain tsvectors that were created with different text search configurations, and there would be no way to guess which was which. It would be impossible to dump and restore such an index correctly.

Because the two-argument version of to_tsvector was used in the index above, only a query reference that uses the 2-argument version of to_tsvector with the same configuration name will use that index. That is, WHERE to_tsvector('english', body) @@ 'a & b' can use the index, but WHERE to_tsvector(body) @@ 'a & b' cannot. This ensures that an index will be used only with the same configuration used to create the index entries.

It is possible to set up more complex expression indexes wherein the configuration name is specified by another column, e.g.:

```
CREATE INDEX pgweb_idx ON pgweb USING gin(to_tsvector(config_name, body));
```

where config_name is a column in the pgweb table. This allows mixed configurations in the same index while recording which configuration was used for each index entry. This would be useful, for example, if the document collection contained documents in different languages. Again, queries that are meant to use the index must be phrased to match, e.g., WHERE to_tsvector(config_name, body) @@ 'a & b'.

Indexes can even concatenate columns:

```
CREATE INDEX pgweb_idx ON pgweb USING gin(to_tsvector('english', title || ' ' || body));
```

Another approach is to create a separate `tsvector` column to hold the output of `to_tsvector`. This example is a concatenation of `title` and `body`, using `coalesce` to ensure that one field will still be indexed when the other is `NULL`:

```
ALTER TABLE pgweb ADD COLUMN textsearchable_index_col tsvector;
UPDATE pgweb SET textsearchable_index_col =
     to_tsvector('english', coalesce(title,'') || ' ' || coalesce(body,''));
```

Then we create a GIN index to speed up the search:

```
CREATE INDEX textsearch_idx ON pgweb USING gin(textsearchable_index_col);
```

Now we are ready to perform a fast full text search:

```
SELECT title
FROM pgweb
WHERE textsearchable_index_col @@ to_tsquery('create & table')
ORDER BY last_mod_date DESC
LIMIT 10;
```

When using a separate column to store the `tsvector` representation, it is necessary to create a trigger to keep the `tsvector` column current anytime `title` or `body` changes. Section 12.4.3 explains how to do that.

One advantage of the separate-column approach over an expression index is that it is not necessary to explicitly specify the text search configuration in queries in order to make use of the index. As shown in the example above, the query can depend on `default_text_search_config`. Another advantage is that searches will be faster, since it will not be necessary to redo the `to_tsvector` calls to verify index matches. (This is more important when using a GiST index than a GIN index; see Section 12.9.) The expression-index approach is simpler to set up, however, and it requires less disk space since the `tsvector` representation is not stored explicitly.

12.3. Controlling Text Search

To implement full text searching there must be a function to create a `tsvector` from a document and a `tsquery` from a user query. Also, we need to return results in a useful order, so we need a function that compares documents with respect to their relevance to the query. It's also important to be able to display the results nicely. PostgreSQL provides support for all of these functions.

12.3.1. Parsing Documents

PostgreSQL provides the function `to_tsvector` for converting a document to the `tsvector` data type.

```
to_tsvector([ config regconfig, ] document text) returns tsvector
```

to_tsvector parses a textual document into tokens, reduces the tokens to lexemes, and returns a tsvector which lists the lexemes together with their positions in the document. The document is processed according to the specified or default text search configuration. Here is a simple example:

```
SELECT to_tsvector('english', 'a fat  cat sat on a mat - it ate a fat rats');
                  to_tsvector
-----------------------------------------------------
 'ate':9 'cat':3 'fat':2,11 'mat':7 'rat':12 'sat':4
```

In the example above we see that the resulting tsvector does not contain the words a, on, or it, the word rats became rat, and the punctuation sign - was ignored.

The to_tsvector function internally calls a parser which breaks the document text into tokens and assigns a type to each token. For each token, a list of dictionaries (Section 12.6) is consulted, where the list can vary depending on the token type. The first dictionary that *recognizes* the token emits one or more normalized *lexemes* to represent the token. For example, rats became rat because one of the dictionaries recognized that the word rats is a plural form of rat. Some words are recognized as *stop words* (Section 12.6.1), which causes them to be ignored since they occur too frequently to be useful in searching. In our example these are a, on, and it. If no dictionary in the list recognizes the token then it is also ignored. In this example that happened to the punctuation sign - because there are in fact no dictionaries assigned for its token type (Space symbols), meaning space tokens will never be indexed. The choices of parser, dictionaries and which types of tokens to index are determined by the selected text search configuration (Section 12.7). It is possible to have many different configurations in the same database, and predefined configurations are available for various languages. In our example we used the default configuration english for the English language.

The function setweight can be used to label the entries of a tsvector with a given *weight*, where a weight is one of the letters A, B, C, or D. This is typically used to mark entries coming from different parts of a document, such as title versus body. Later, this information can be used for ranking of search results.

Because to_tsvector(NULL) will return NULL, it is recommended to use coalesce whenever a field might be null. Here is the recommended method for creating a tsvector from a structured document:

```
UPDATE tt SET ti =
    setweight(to_tsvector(coalesce(title,")), 'A')    ||
    setweight(to_tsvector(coalesce(keyword,")), 'B')  ||
    setweight(to_tsvector(coalesce(abstract,")), 'C') ||
    setweight(to_tsvector(coalesce(body,")), 'D');
```

Here we have used setweight to label the source of each lexeme in the finished tsvector, and then merged the labeled tsvector values using the tsvector concatenation operator ||. (Section 12.4.1 gives details about these operations.)

12.3.2. Parsing Queries

PostgreSQL provides the functions to_tsquery and plainto_tsquery for converting a query to the tsquery data type. to_tsquery offers access to more features than plainto_tsquery, but is less forgiving about its input.

```
to_tsquery([ config regconfig, ] querytext text) returns tsquery
```

to_tsquery creates a tsquery value from *querytext*, which must consist of single tokens separated by the Boolean operators & (AND), | (OR) and ! (NOT). These operators can be grouped using parentheses. In other words, the input to to_tsquery must already follow the general rules for tsquery input, as described in Section 8.11. The difference is that while basic tsquery input takes the tokens at face value, to_tsquery normalizes each token to a lexeme using the specified or default configuration, and discards any tokens that are stop words according to the configuration. For example:

```
SELECT to_tsquery('english', 'The & Fat & Rats');
  to_tsquery
---------------
 'fat' & 'rat'
```

As in basic tsquery input, weight(s) can be attached to each lexeme to restrict it to match only tsvector lexemes of those weight(s). For example:

```
SELECT to_tsquery('english', 'Fat | Rats:AB');
    to_tsquery
------------------
 'fat' | 'rat':AB
```

Also, * can be attached to a lexeme to specify prefix matching:

```
SELECT to_tsquery('supern:*A & star:A*B');
        to_tsquery
--------------------------
 'supern':*A & 'star':*AB
```

Such a lexeme will match any word in a tsvector that begins with the given string.

to_tsquery can also accept single-quoted phrases. This is primarily useful when the configuration includes a thesaurus dictionary that may trigger on such phrases. In the example below, a thesaurus contains the rule supernovae stars : sn:

```
SELECT to_tsquery('''supernovae stars'' & !crab');
  to_tsquery
---------------
 'sn' & !'crab'
```

Without quotes, to_tsquery will generate a syntax error for tokens that are not separated by an AND or OR operator.

```
plainto_tsquery([ config regconfig, ] querytext text) returns tsquery
```

plainto_tsquery transforms unformatted text *querytext* to tsquery. The text is parsed and normalized much as for to_tsvector, then the & (AND) Boolean operator is inserted between surviving words.

Example:

```
SELECT plainto_tsquery('english', 'The Fat Rats');
 plainto_tsquery
-----------------
 'fat' & 'rat'
```

Note that plainto_tsquery cannot recognize Boolean operators, weight labels, or prefix-match labels in its input:

```
SELECT plainto_tsquery('english', 'The Fat & Rats:C');
   plainto_tsquery
---------------------
 'fat' & 'rat' & 'c'
```

Here, all the input punctuation was discarded as being space symbols.

12.3.3. Ranking Search Results

Ranking attempts to measure how relevant documents are to a particular query, so that when there are many matches the most relevant ones can be shown first. PostgreSQL provides two predefined ranking functions, which take into account lexical, proximity, and structural information; that is, they consider how often the query terms appear in the document, how close together the terms are in the document, and how important is the part of the document where they occur. However, the concept of relevancy is vague and very application-specific. Different applications might require additional information for ranking, e.g., document modification time. The built-in ranking functions are only examples. You can write your own ranking functions and/or combine their results with additional factors to fit your specific needs.

The two ranking functions currently available are:

`ts_rank([ weights float4[], ] vector tsvector, query tsquery [, normalization integer ]) returns float4`

Ranks vectors based on the frequency of their matching lexemes.

`ts_rank_cd([ weights float4[], ] vector tsvector, query tsquery [, normalization integer ]) returns float4`

This function computes the *cover density* ranking for the given document vector and query, as described in Clarke, Cormack, and Tudhope's "Relevance Ranking for One to Three Term Queries" in the journal "Information Processing and Management", 1999. Cover density is similar to `ts_rank` ranking except that the proximity of matching lexemes to each other is taken into consideration.

This function requires lexeme positional information to perform its calculation. Therefore, it ignores any "stripped" lexemes in the `tsvector`. If there are no unstripped lexemes in the input, the result will be zero. (See Section 12.4.1 for more information about the `strip` function and positional information in `tsvector`s.)

For both these functions, the optional *weights* argument offers the ability to weigh word instances more or less heavily depending on how they are labeled. The weight arrays specify how heavily to weigh each category of word, in the order:

```
{D-weight, C-weight, B-weight, A-weight}
```

If no *weights* are provided, then these defaults are used:

```
{0.1, 0.2, 0.4, 1.0}
```

Typically weights are used to mark words from special areas of the document, like the title or an initial abstract, so they can be treated with more or less importance than words in the document body.

Since a longer document has a greater chance of containing a query term it is reasonable to take into account document size, e.g., a hundred-word document with five instances of a search word is

probably more relevant than a thousand-word document with five instances. Both ranking functions take an integer *normalization* option that specifies whether and how a document's length should impact its rank. The integer option controls several behaviors, so it is a bit mask: you can specify one or more behaviors using | (for example, 2|4).

- 0 (the default) ignores the document length
- 1 divides the rank by 1 + the logarithm of the document length
- 2 divides the rank by the document length
- 4 divides the rank by the mean harmonic distance between extents (this is implemented only by ts_rank_cd)
- 8 divides the rank by the number of unique words in document
- 16 divides the rank by 1 + the logarithm of the number of unique words in document
- 32 divides the rank by itself + 1

If more than one flag bit is specified, the transformations are applied in the order listed.

It is important to note that the ranking functions do not use any global information, so it is impossible to produce a fair normalization to 1% or 100% as sometimes desired. Normalization option 32 (rank/(rank+1)) can be applied to scale all ranks into the range zero to one, but of course this is just a cosmetic change; it will not affect the ordering of the search results.

Here is an example that selects only the ten highest-ranked matches:

```
SELECT title, ts_rank_cd(textsearch, query) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
                     title                     |   rank
-----------------------------------------------+----------
 Neutrinos in the Sun                          |      3.1
 The Sudbury Neutrino Detector                 |      2.4
 A MACHO View of Galactic Dark Matter          |  2.01317
 Hot Gas and Dark Matter                       |  1.91171
 The Virgo Cluster: Hot Plasma and Dark Matter |  1.90953
 Rafting for Solar Neutrinos                   |      1.9
 NGC 4650A: Strange Galaxy and Dark Matter     |  1.85774
 Hot Gas and Dark Matter                       |   1.6123
 Ice Fishing for Cosmic Neutrinos              |      1.6
 Weak Lensing Distorts the Universe            | 0.818218
```

This is the same example using normalized ranking:

```
SELECT title, ts_rank_cd(textsearch, query, 32 /* rank/(rank+1) */ ) AS rank
FROM apod, to_tsquery('neutrino|(dark & matter)') query
WHERE  query @@ textsearch
ORDER BY rank DESC
LIMIT 10;
                     title                     |        rank
-----------------------------------------------+-------------------
 Neutrinos in the Sun                          | 0.756097569485493
 The Sudbury Neutrino Detector                 | 0.705882361190954
 A MACHO View of Galactic Dark Matter          | 0.668123210574724
 Hot Gas and Dark Matter                       |  0.65655958650282
 The Virgo Cluster: Hot Plasma and Dark Matter | 0.656301290640973
 Rafting for Solar Neutrinos                   | 0.655172410958162
 NGC 4650A: Strange Galaxy and Dark Matter     | 0.650072921219637
```

```
 Hot Gas and Dark Matter                        | 0.617195790024749
 Ice Fishing for Cosmic Neutrinos               | 0.615384618911517
 Weak Lensing Distorts the Universe             | 0.450010798361481
```

Ranking can be expensive since it requires consulting the `tsvector` of each matching document, which can be I/O bound and therefore slow. Unfortunately, it is almost impossible to avoid since practical queries often result in large numbers of matches.

12.3.4. Highlighting Results

To present search results it is ideal to show a part of each document and how it is related to the query. Usually, search engines show fragments of the document with marked search terms. PostgreSQL provides a function `ts_headline` that implements this functionality.

```
ts_headline([ config regconfig, ] document text, query tsquery [, options text ]) returns tex
```

`ts_headline` accepts a document along with a query, and returns an excerpt from the document in which terms from the query are highlighted. The configuration to be used to parse the document can be specified by *`config`*; if *`config`* is omitted, the `default_text_search_config` configuration is used.

If an *`options`* string is specified it must consist of a comma-separated list of one or more *`option=value`* pairs. The available options are:

- `StartSel`, `StopSel`: the strings with which to delimit query words appearing in the document, to distinguish them from other excerpted words. You must double-quote these strings if they contain spaces or commas.
- `MaxWords`, `MinWords`: these numbers determine the longest and shortest headlines to output.
- `ShortWord`: words of this length or less will be dropped at the start and end of a headline. The default value of three eliminates common English articles.
- `HighlightAll`: Boolean flag; if `true` the whole document will be used as the headline, ignoring the preceding three parameters.
- `MaxFragments`: maximum number of text excerpts or fragments to display. The default value of zero selects a non-fragment-oriented headline generation method. A value greater than zero selects fragment-based headline generation. This method finds text fragments with as many query words as possible and stretches those fragments around the query words. As a result query words are close to the middle of each fragment and have words on each side. Each fragment will be of at most `MaxWords` and words of length `ShortWord` or less are dropped at the start and end of each fragment. If not all query words are found in the document, then a single fragment of the first `MinWords` in the document will be displayed.
- `FragmentDelimiter`: When more than one fragment is displayed, the fragments will be separated by this string.

Any unspecified options receive these defaults:

```
StartSel=<b>, StopSel=</b>,
MaxWords=35, MinWords=15, ShortWord=3, HighlightAll=FALSE,
MaxFragments=0, FragmentDelimiter=" ... "
```

For example:

```
SELECT ts_headline('english',
  'The most common type of search
is to find all documents containing given query terms
and return them in order of their similarity to the
query.',
  to_tsquery('query & similarity'));
                        ts_headline
------------------------------------------------------------
 containing given <b>query</b> terms
 and return them in order of their <b>similarity</b> to the
 <b>query</b>.

SELECT ts_headline('english',
  'The most common type of search
is to find all documents containing given query terms
and return them in order of their similarity to the
query.',
  to_tsquery('query & similarity'),
  'StartSel = <, StopSel = >');
                       ts_headline
-------------------------------------------------------
 containing given <query> terms
 and return them in order of their <similarity> to the
 <query>.
```

`ts_headline` uses the original document, not a `tsvector` summary, so it can be slow and should be used with care. A typical mistake is to call `ts_headline` for *every* matching document when only ten documents are to be shown. SQL subqueries can help; here is an example:

```
SELECT id, ts_headline(body, q), rank
FROM (SELECT id, body, q, ts_rank_cd(ti, q) AS rank
      FROM apod, to_tsquery('stars') q
      WHERE ti @@ q
      ORDER BY rank DESC
      LIMIT 10) AS foo;
```

12.4. Additional Features

This section describes additional functions and operators that are useful in connection with text search.

12.4.1. Manipulating Documents

Section 12.3.1 showed how raw textual documents can be converted into `tsvector` values. PostgreSQL also provides functions and operators that can be used to manipulate documents that are already in `tsvector` form.

`tsvector || tsvector`

The `tsvector` concatenation operator returns a vector which combines the lexemes and positional information of the two vectors given as arguments. Positions and weight labels are retained during the concatenation. Positions appearing in the right-hand vector are offset by the largest position mentioned in the left-hand vector, so that the result is nearly equivalent to the result of performing `to_tsvector` on the concatenation of the two original document strings. (The equivalence is not exact, because any stop-words removed from the end of the left-hand argument will not affect the result, whereas they would have affected the positions of the lexemes in the right-hand argument if textual concatenation were used.)

One advantage of using concatenation in the vector form, rather than concatenating text before applying `to_tsvector`, is that you can use different configurations to parse different sections of the document. Also, because the `setweight` function marks all lexemes of the given vector the same way, it is necessary to parse the text and do `setweight` before concatenating if you want to label different parts of the document with different weights.

`setweight(`*`vector`* `tsvector, `*`weight`* `"char") returns tsvector`

`setweight` returns a copy of the input vector in which every position has been labeled with the given *`weight`*, either `A`, `B`, `C`, or `D`. (`D` is the default for new vectors and as such is not displayed on output.) These labels are retained when vectors are concatenated, allowing words from different parts of a document to be weighted differently by ranking functions.

Note that weight labels apply to *positions*, not *lexemes*. If the input vector has been stripped of positions then `setweight` does nothing.

`length(`*`vector`* `tsvector) returns integer`

Returns the number of lexemes stored in the vector.

`strip(`*`vector`* `tsvector) returns tsvector`

Returns a vector which lists the same lexemes as the given vector, but which lacks any position or weight information. While the returned vector is much less useful than an unstripped vector for relevance ranking, it will usually be much smaller.

12.4.2. Manipulating Queries

Section 12.3.2 showed how raw textual queries can be converted into `tsquery` values. PostgreSQL also provides functions and operators that can be used to manipulate queries that are already in `tsquery` form.

`tsquery && tsquery`

Returns the AND-combination of the two given queries.

`tsquery || tsquery`

Returns the OR-combination of the two given queries.

`!! tsquery`

Returns the negation (NOT) of the given query.

`numnode(`*`query`* `tsquery) returns integer`

Returns the number of nodes (lexemes plus operators) in a `tsquery`. This function is useful to determine if the *`query`* is meaningful (returns > 0), or contains only stop words (returns 0).

Examples:

```
SELECT numnode(plainto_tsquery('the any'));
NOTICE:  query contains only stopword(s) or doesn't contain lexeme(s), ignored
 numnode
---------
       0

SELECT numnode('foo & bar'::tsquery);
 numnode
---------
       3
```

`querytree(`*`query`* `tsquery) returns text`

Returns the portion of a `tsquery` that can be used for searching an index. This function is useful for detecting unindexable queries, for example those containing only stop words or only negated terms. For example:

```
SELECT querytree(to_tsquery('!defined'));
 querytree
-----------
```

12.4.2.1. Query Rewriting

The `ts_rewrite` family of functions search a given `tsquery` for occurrences of a target subquery, and replace each occurrence with a substitute subquery. In essence this operation is a `tsquery`-specific version of substring replacement. A target and substitute combination can be thought of as a *query rewrite rule*. A collection of such rewrite rules can be a powerful search aid. For example, you can expand the search using synonyms (e.g., `new york`, `big apple`, `nyc`, `gotham`) or narrow the search to direct the user to some hot topic. There is some overlap in functionality between this feature and thesaurus dictionaries (Section 12.6.4). However, you can modify a set of rewrite rules on-the-fly without reindexing, whereas updating a thesaurus requires reindexing to be effective.

`ts_rewrite (`*`query`* `tsquery,` *`target`* `tsquery,` *`substitute`* `tsquery) returns tsquery`

This form of `ts_rewrite` simply applies a single rewrite rule: *`target`* is replaced by *`substitute`* wherever it appears in *`query`*. For example:

```
SELECT ts_rewrite('a & b'::tsquery, 'a'::tsquery, 'c'::tsquery);
 ts_rewrite
------------
 'b' & 'c'
```

`ts_rewrite (`*`query`* `tsquery,` *`select`* `text) returns tsquery`

This form of `ts_rewrite` accepts a starting *`query`* and a SQL *`select`* command, which is given as a text string. The *`select`* must yield two columns of `tsquery` type. For each row of the *`select`* result, occurrences of the first column value (the target) are replaced by the second column value (the substitute) within the current *`query`* value. For example:

```
CREATE TABLE aliases (t tsquery PRIMARY KEY, s tsquery);
INSERT INTO aliases VALUES('a', 'c');

SELECT ts_rewrite('a & b'::tsquery, 'SELECT t,s FROM aliases');
 ts_rewrite
------------
 'b' & 'c'
```

Note that when multiple rewrite rules are applied in this way, the order of application can be important; so in practice you will want the source query to ORDER BY some ordering key.

Let's consider a real-life astronomical example. We'll expand query supernovae using table-driven rewriting rules:

```
CREATE TABLE aliases (t tsquery primary key, s tsquery);
INSERT INTO aliases VALUES(to_tsquery('supernovae'), to_tsquery('supernovae|sn'));

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM aliases');
           ts_rewrite
---------------------------------
 'crab' & ( 'supernova' | 'sn' )
```

We can change the rewriting rules just by updating the table:

```
UPDATE aliases
SET s = to_tsquery('supernovae|sn & !nebulae')
WHERE t = to_tsquery('supernovae');

SELECT ts_rewrite(to_tsquery('supernovae & crab'), 'SELECT * FROM aliases');
                 ts_rewrite
---------------------------------------------
 'crab' & ( 'supernova' | 'sn' & !'nebula' )
```

Rewriting can be slow when there are many rewriting rules, since it checks every rule for a possible match. To filter out obvious non-candidate rules we can use the containment operators for the tsquery type. In the example below, we select only those rules which might match the original query:

```
SELECT ts_rewrite('a & b'::tsquery,
                  'SELECT t,s FROM aliases WHERE "a & b"::tsquery @> t');
 ts_rewrite
------------
 'b' & 'c'
```

12.4.3. Triggers for Automatic Updates

When using a separate column to store the tsvector representation of your documents, it is necessary to create a trigger to update the tsvector column when the document content columns change. Two built-in trigger functions are available for this, or you can write your own.

```
tsvector_update_trigger(tsvector_column_name, config_name, text_column_name [, ... ])
tsvector_update_trigger_column(tsvector_column_name, config_column_name, text_column_name [,
```

These trigger functions automatically compute a tsvector column from one or more textual columns, under the control of parameters specified in the CREATE TRIGGER command. An example of their use is:

```
CREATE TABLE messages (
    title       text,
    body        text,
```

```
    tsv         tsvector
);

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
ON messages FOR EACH ROW EXECUTE PROCEDURE
tsvector_update_trigger(tsv, 'pg_catalog.english', title, body);

INSERT INTO messages VALUES('title here', 'the body text is here');

SELECT * FROM messages;
   title    |         body          |            tsv
------------+-----------------------+----------------------------
 title here | the body text is here | 'bodi':4 'text':5 'titl':1

SELECT title, body FROM messages WHERE tsv @@ to_tsquery('title & body');
   title    |         body
------------+-----------------------
 title here | the body text is here
```

Having created this trigger, any change in `title` or `body` will automatically be reflected into `tsv`, without the application having to worry about it.

The first trigger argument must be the name of the `tsvector` column to be updated. The second argument specifies the text search configuration to be used to perform the conversion. For `tsvector_update_trigger`, the configuration name is simply given as the second trigger argument. It must be schema-qualified as shown above, so that the trigger behavior will not change with changes in `search_path`. For `tsvector_update_trigger_column`, the second trigger argument is the name of another table column, which must be of type `regconfig`. This allows a per-row selection of configuration to be made. The remaining argument(s) are the names of textual columns (of type `text`, `varchar`, or `char`). These will be included in the document in the order given. NULL values will be skipped (but the other columns will still be indexed).

A limitation of these built-in triggers is that they treat all the input columns alike. To process columns differently — for example, to weight title differently from body — it is necessary to write a custom trigger. Here is an example using PL/pgSQL as the trigger language:

```
CREATE FUNCTION messages_trigger() RETURNS trigger AS $$
begin
  new.tsv :=
     setweight(to_tsvector('pg_catalog.english', coalesce(new.title,")), 'A') ||
     setweight(to_tsvector('pg_catalog.english', coalesce(new.body,")), 'D');
  return new;
end
$$ LANGUAGE plpgsql;

CREATE TRIGGER tsvectorupdate BEFORE INSERT OR UPDATE
    ON messages FOR EACH ROW EXECUTE PROCEDURE messages_trigger();
```

Keep in mind that it is important to specify the configuration name explicitly when creating `tsvector` values inside triggers, so that the column's contents will not be affected by changes to `default_text_search_config`. Failure to do this is likely to lead to problems such as search results changing after a dump and reload.

12.4.4. Gathering Document Statistics

The function `ts_stat` is useful for checking your configuration and for finding stop-word candidates.

```
ts_stat(sqlquery text, [ weights text, ]
        OUT word text, OUT ndoc integer,
        OUT nentry integer) returns setof record
```

sqlquery is a text value containing an SQL query which must return a single `tsvector` column. `ts_stat` executes the query and returns statistics about each distinct lexeme (word) contained in the `tsvector` data. The columns returned are

- *word* `text` — the value of a lexeme
- *ndoc* `integer` — number of documents (`tsvector`s) the word occurred in
- *nentry* `integer` — total number of occurrences of the word

If *weights* is supplied, only occurrences having one of those weights are counted.

For example, to find the ten most frequent words in a document collection:

```
SELECT * FROM ts_stat('SELECT vector FROM apod')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

The same, but counting only word occurrences with weight `A` or `B`:

```
SELECT * FROM ts_stat('SELECT vector FROM apod', 'ab')
ORDER BY nentry DESC, ndoc DESC, word
LIMIT 10;
```

12.5. Parsers

Text search parsers are responsible for splitting raw document text into *tokens* and identifying each token's type, where the set of possible types is defined by the parser itself. Note that a parser does not modify the text at all — it simply identifies plausible word boundaries. Because of this limited scope, there is less need for application-specific custom parsers than there is for custom dictionaries. At present PostgreSQL provides just one built-in parser, which has been found to be useful for a wide range of applications.

The built-in parser is named `pg_catalog.default`. It recognizes 23 token types, shown in Table 12-1.

Table 12-1. Default Parser's Token Types

Alias	Description	Example
`asciiword`	Word, all ASCII letters	`elephant`
`word`	Word, all letters	`mañana`
`numword`	Word, letters and digits	`beta1`
`asciihword`	Hyphenated word, all ASCII	`up-to-date`

Alias	Description	Example
hword	Hyphenated word, all letters	lógico-matemática
numhword	Hyphenated word, letters and digits	postgresql-beta1
hword_asciipart	Hyphenated word part, all ASCII	postgresql in the context postgresql-beta1
hword_part	Hyphenated word part, all letters	lógico or matemática in the context lógico-matemática
hword_numpart	Hyphenated word part, letters and digits	beta1 in the context postgresql-beta1
email	Email address	foo@example.com
protocol	Protocol head	http://
url	URL	example.com/stuff/index.html
host	Host	example.com
url_path	URL path	/stuff/index.html, in the context of a URL
file	File or path name	/usr/local/foo.txt, if not within a URL
sfloat	Scientific notation	-1.234e56
float	Decimal notation	-1.234
int	Signed integer	-1234
uint	Unsigned integer	1234
version	Version number	8.3.0
tag	XML tag	<a href="dictionaries.html">
entity	XML entity	&
blank	Space symbols	(any whitespace or punctuation not otherwise recognized)

> **Note:** The parser's notion of a "letter" is determined by the database's locale setting, specifically lc_ctype. Words containing only the basic ASCII letters are reported as a separate token type, since it is sometimes useful to distinguish them. In most European languages, token types word and asciiword should be treated alike.
>
> email does not support all valid email characters as defined by RFC 5322. Specifically, the only non-alphanumeric characters supported for email user names are period, dash, and underscore.

It is possible for the parser to produce overlapping tokens from the same piece of text. As an example, a hyphenated word will be reported both as the entire word and as each component:

```
SELECT alias, description, token FROM ts_debug('foo-bar-beta1');
      alias      |               description                |     token
-----------------+------------------------------------------+---------------
 numhword        | Hyphenated word, letters and digits      | foo-bar-beta1
 hword_asciipart | Hyphenated word part, all ASCII          | foo
 blank           | Space symbols                            | -
```

```
 hword_asciipart | Hyphenated word part, all ASCII          | bar
 blank           | Space symbols                             | -
 hword_numpart   | Hyphenated word part, letters and digits | beta1
```

This behavior is desirable since it allows searches to work for both the whole compound word and for components. Here is another instructive example:

```
SELECT alias, description, token FROM ts_debug('http://example.com/stuff/index.html');
  alias   |  description  |            token
----------+---------------+------------------------------
 protocol | Protocol head | http://
 url      | URL           | example.com/stuff/index.html
 host     | Host          | example.com
 url_path | URL path      | /stuff/index.html
```

12.6. Dictionaries

Dictionaries are used to eliminate words that should not be considered in a search (*stop words*), and to *normalize* words so that different derived forms of the same word will match. A successfully normalized word is called a *lexeme*. Aside from improving search quality, normalization and removal of stop words reduce the size of the `tsvector` representation of a document, thereby improving performance. Normalization does not always have linguistic meaning and usually depends on application semantics.

Some examples of normalization:

- Linguistic - Ispell dictionaries try to reduce input words to a normalized form; stemmer dictionaries remove word endings
- URL locations can be canonicalized to make equivalent URLs match:
  - http://www.pgsql.ru/db/mw/index.html
  - http://www.pgsql.ru/db/mw/
  - http://www.pgsql.ru/db/../db/mw/index.html
- Color names can be replaced by their hexadecimal values, e.g., `red, green, blue, magenta -> FF0000, 00FF00, 0000FF, FF00FF`
- If indexing numbers, we can remove some fractional digits to reduce the range of possible numbers, so for example *3.14*159265359, *3.14*15926, *3.14* will be the same after normalization if only two digits are kept after the decimal point.

A dictionary is a program that accepts a token as input and returns:

- an array of lexemes if the input token is known to the dictionary (notice that one token can produce more than one lexeme)
- a single lexeme with the `TSL_FILTER` flag set, to replace the original token with a new token to be passed to subsequent dictionaries (a dictionary that does this is called a *filtering dictionary*)
- an empty array if the dictionary knows the token, but it is a stop word
- `NULL` if the dictionary does not recognize the input token

PostgreSQL provides predefined dictionaries for many languages. There are also several predefined templates that can be used to create new dictionaries with custom parameters. Each predefined dictionary template is described below. If no existing template is suitable, it is possible to create new ones; see the `contrib/` area of the PostgreSQL distribution for examples.

A text search configuration binds a parser together with a set of dictionaries to process the parser's output tokens. For each token type that the parser can return, a separate list of dictionaries is specified by the configuration. When a token of that type is found by the parser, each dictionary in the list is consulted in turn, until some dictionary recognizes it as a known word. If it is identified as a stop word, or if no dictionary recognizes the token, it will be discarded and not indexed or searched for. Normally, the first dictionary that returns a non-`NULL` output determines the result, and any remaining dictionaries are not consulted; but a filtering dictionary can replace the given word with a modified word, which is then passed to subsequent dictionaries.

The general rule for configuring a list of dictionaries is to place first the most narrow, most specific dictionary, then the more general dictionaries, finishing with a very general dictionary, like a Snowball stemmer or `simple`, which recognizes everything. For example, for an astronomy-specific search (`astro_en` configuration) one could bind token type `asciiword` (ASCII word) to a synonym dictionary of astronomical terms, a general English dictionary and a Snowball English stemmer:

```
ALTER TEXT SEARCH CONFIGURATION astro_en
    ADD MAPPING FOR asciiword WITH astrosyn, english_ispell, english_stem;
```

A filtering dictionary can be placed anywhere in the list, except at the end where it'd be useless. Filtering dictionaries are useful to partially normalize words to simplify the task of later dictionaries. For example, a filtering dictionary could be used to remove accents from accented letters, as is done by the unaccent module.

12.6.1. Stop Words

Stop words are words that are very common, appear in almost every document, and have no discrimination value. Therefore, they can be ignored in the context of full text searching. For example, every English text contains words like `a` and `the`, so it is useless to store them in an index. However, stop words do affect the positions in `tsvector`, which in turn affect ranking:

```
SELECT to_tsvector('english','in the list of stop words');
        to_tsvector
----------------------------
 'list':3 'stop':5 'word':6
```

The missing positions 1,2,4 are because of stop words. Ranks calculated for documents with and without stop words are quite different:

```
SELECT ts_rank_cd (to_tsvector('english','in the list of stop words'), to_tsquery('list
 ts_rank_cd
------------
       0.05

SELECT ts_rank_cd (to_tsvector('english','list stop words'), to_tsquery('list & stop'));
 ts_rank_cd
------------
        0.1
```

It is up to the specific dictionary how it treats stop words. For example, `ispell` dictionaries first normalize words and then look at the list of stop words, while `Snowball` stemmers first check the list of stop words. The reason for the different behavior is an attempt to decrease noise.

12.6.2. Simple Dictionary

The `simple` dictionary template operates by converting the input token to lower case and checking it against a file of stop words. If it is found in the file then an empty array is returned, causing the token to be discarded. If not, the lower-cased form of the word is returned as the normalized lexeme. Alternatively, the dictionary can be configured to report non-stop-words as unrecognized, allowing them to be passed on to the next dictionary in the list.

Here is an example of a dictionary definition using the `simple` template:

```
CREATE TEXT SEARCH DICTIONARY public.simple_dict (
    TEMPLATE = pg_catalog.simple,
    STOPWORDS = english
);
```

Here, `english` is the base name of a file of stop words. The file's full name will be `$SHAREDIR/tsearch_data/english.stop`, where `$SHAREDIR` means the PostgreSQL installation's shared-data directory, often `/usr/local/share/postgresql` (use `pg_config --sharedir` to determine it if you're not sure). The file format is simply a list of words, one per line. Blank lines and trailing spaces are ignored, and upper case is folded to lower case, but no other processing is done on the file contents.

Now we can test our dictionary:

```
SELECT ts_lexize('public.simple_dict','YeS');
 ts_lexize
-----------
 {yes}

SELECT ts_lexize('public.simple_dict','The');
 ts_lexize
-----------
 {}
```

We can also choose to return `NULL`, instead of the lower-cased word, if it is not found in the stop words file. This behavior is selected by setting the dictionary's `Accept` parameter to `false`. Continuing the example:

```
ALTER TEXT SEARCH DICTIONARY public.simple_dict ( Accept = false );

SELECT ts_lexize('public.simple_dict','YeS');
 ts_lexize
-----------


SELECT ts_lexize('public.simple_dict','The');
 ts_lexize
-----------
 {}
```

With the default setting of `Accept = true`, it is only useful to place a `simple` dictionary at the end of a list of dictionaries, since it will never pass on any token to a following dictionary. Conversely, `Accept = false` is only useful when there is at least one following dictionary.

Caution

Most types of dictionaries rely on configuration files, such as files of stop words. These files *must* be stored in UTF-8 encoding. They will be translated to the actual database encoding, if that is different, when they are read into the server.

Caution

Normally, a database session will read a dictionary configuration file only once, when it is first used within the session. If you modify a configuration file and want to force existing sessions to pick up the new contents, issue an `ALTER TEXT SEARCH DICTIONARY` command on the dictionary. This can be a "dummy" update that doesn't actually change any parameter values.

12.6.3. Synonym Dictionary

This dictionary template is used to create dictionaries that replace a word with a synonym. Phrases are not supported (use the thesaurus template (Section 12.6.4) for that). A synonym dictionary can be used to overcome linguistic problems, for example, to prevent an English stemmer dictionary from reducing the word "Paris" to "pari". It is enough to have a `Paris paris` line in the synonym dictionary and put it before the `english_stem` dictionary. For example:

```
SELECT * FROM ts_debug('english', 'Paris');
   alias   |   description   | token |  dictionaries  |  dictionary  | lexemes
-----------+-----------------+-------+----------------+--------------+---------
 asciiword | Word, all ASCII | Paris | {english_stem} | english_stem | {pari}

CREATE TEXT SEARCH DICTIONARY my_synonym (
    TEMPLATE = synonym,
    SYNONYMS = my_synonyms
);

ALTER TEXT SEARCH CONFIGURATION english
    ALTER MAPPING FOR asciiword
    WITH my_synonym, english_stem;

SELECT * FROM ts_debug('english', 'Paris');
   alias   |   description   | token |       dictionaries        | dictionary | lexemes
-----------+-----------------+-------+---------------------------+------------+---------
 asciiword | Word, all ASCII | Paris | {my_synonym,english_stem} | my_synonym | {paris}
```

The only parameter required by the `synonym` template is `SYNONYMS`, which is the base name of its configuration file — `my_synonyms` in the above example. The file's full name will be `$SHAREDIR/tsearch_data/my_synonyms.syn` (where `$SHAREDIR` means the PostgreSQL installation's shared-data directory). The file format is just one line per word to be substituted, with

the word followed by its synonym, separated by white space. Blank lines and trailing spaces are ignored.

The `synonym` template also has an optional parameter `CaseSensitive`, which defaults to `false`. When `CaseSensitive` is `false`, words in the synonym file are folded to lower case, as are input tokens. When it is `true`, words and tokens are not folded to lower case, but are compared as-is.

An asterisk (`*`) can be placed at the end of a synonym in the configuration file. This indicates that the synonym is a prefix. The asterisk is ignored when the entry is used in `to_tsvector()`, but when it is used in `to_tsquery()`, the result will be a query item with the prefix match marker (see Section 12.3.2). For example, suppose we have these entries in `$SHAREDIR/tsearch_data/synonym_sample.syn`:

```
postgres        pgsql
postgresql      pgsql
postgre pgsql
gogle   googl
indices index*
```

Then we will get these results:

```
mydb=# CREATE TEXT SEARCH DICTIONARY syn (template=synonym, synonyms='synonym_sample');
mydb=# SELECT ts_lexize('syn','indices');
 ts_lexize
-----------
 {index}
(1 row)

mydb=# CREATE TEXT SEARCH CONFIGURATION tst (copy=simple);
mydb=# ALTER TEXT SEARCH CONFIGURATION tst ALTER MAPPING FOR asciiword WITH syn;
mydb=# SELECT to_tsvector('tst','indices');
 to_tsvector
-------------
 'index':1
(1 row)

mydb=# SELECT to_tsquery('tst','indices');
 to_tsquery
------------
 'index':*
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector;
            tsvector
---------------------------------
 'are' 'indexes' 'useful' 'very'
(1 row)

mydb=# SELECT 'indexes are very useful'::tsvector @@ to_tsquery('tst','indices');
 ?column?
----------
 t
(1 row)
```

12.6.4. Thesaurus Dictionary

A thesaurus dictionary (sometimes abbreviated as TZ) is a collection of words that includes information about the relationships of words and phrases, i.e., broader terms (BT), narrower terms (NT), preferred terms, non-preferred terms, related terms, etc.

Basically a thesaurus dictionary replaces all non-preferred terms by one preferred term and, optionally, preserves the original terms for indexing as well. PostgreSQL's current implementation of the thesaurus dictionary is an extension of the synonym dictionary with added *phrase* support. A thesaurus dictionary requires a configuration file of the following format:

```
# this is a comment
sample word(s) : indexed word(s)
more sample word(s) : more indexed word(s)
...
```

where the colon (`:`) symbol acts as a delimiter between a phrase and its replacement.

A thesaurus dictionary uses a *subdictionary* (which is specified in the dictionary's configuration) to normalize the input text before checking for phrase matches. It is only possible to select one subdictionary. An error is reported if the subdictionary fails to recognize a word. In that case, you should remove the use of the word or teach the subdictionary about it. You can place an asterisk (`*`) at the beginning of an indexed word to skip applying the subdictionary to it, but all sample words *must* be known to the subdictionary.

The thesaurus dictionary chooses the longest match if there are multiple phrases matching the input, and ties are broken by using the last definition.

Specific stop words recognized by the subdictionary cannot be specified; instead use `?` to mark the location where any stop word can appear. For example, assuming that `a` and `the` are stop words according to the subdictionary:

```
? one ? two : swsw
```

matches `a one the two` and `the one a two`; both would be replaced by `swsw`.

Since a thesaurus dictionary has the capability to recognize phrases it must remember its state and interact with the parser. A thesaurus dictionary uses these assignments to check if it should handle the next word or stop accumulation. The thesaurus dictionary must be configured carefully. For example, if the thesaurus dictionary is assigned to handle only the `asciiword` token, then a thesaurus dictionary definition like `one 7` will not work since token type `uint` is not assigned to the thesaurus dictionary.

> **Caution**
>
> Thesauruses are used during indexing so any change in the thesaurus dictionary's parameters *requires* reindexing. For most other dictionary types, small changes such as adding or removing stopwords does not force reindexing.

12.6.4.1. Thesaurus Configuration

To define a new thesaurus dictionary, use the `thesaurus` template. For example:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_simple (
    TEMPLATE = thesaurus,
    DictFile = mythesaurus,
    Dictionary = pg_catalog.english_stem
```

```
);
```

Here:

- `thesaurus_simple` is the new dictionary's name
- `mythesaurus` is the base name of the thesaurus configuration file. (Its full name will be `$SHAREDIR/tsearch_data/mythesaurus.ths`, where `$SHAREDIR` means the installation shared-data directory.)
- `pg_catalog.english_stem` is the subdictionary (here, a Snowball English stemmer) to use for thesaurus normalization. Notice that the subdictionary will have its own configuration (for example, stop words), which is not shown here.

Now it is possible to bind the thesaurus dictionary `thesaurus_simple` to the desired token types in a configuration, for example:

```
ALTER TEXT SEARCH CONFIGURATION russian
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart
    WITH thesaurus_simple;
```

12.6.4.2. Thesaurus Example

Consider a simple astronomical thesaurus `thesaurus_astro`, which contains some astronomical word combinations:

```
supernovae stars : sn
crab nebulae : crab
```

Below we create a dictionary and bind some token types to an astronomical thesaurus and English stemmer:

```
CREATE TEXT SEARCH DICTIONARY thesaurus_astro (
    TEMPLATE = thesaurus,
    DictFile = thesaurus_astro,
    Dictionary = english_stem
);

ALTER TEXT SEARCH CONFIGURATION russian
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart
    WITH thesaurus_astro, english_stem;
```

Now we can see how it works. `ts_lexize` is not very useful for testing a thesaurus, because it treats its input as a single token. Instead we can use `plainto_tsquery` and `to_tsvector` which will break their input strings into multiple tokens:

```
SELECT plainto_tsquery('supernova star');
 plainto_tsquery
-----------------
 'sn'

SELECT to_tsvector('supernova star');
 to_tsvector
-------------
```

```
 'sn':1
```

In principle, one can use `to_tsquery` if you quote the argument:

```
SELECT to_tsquery("'supernova star"');
 to_tsquery
------------
 'sn'
```

Notice that `supernova star` matches `supernovae stars` in `thesaurus_astro` because we specified the `english_stem` stemmer in the thesaurus definition. The stemmer removed the `e` and `s`.

To index the original phrase as well as the substitute, just include it in the right-hand part of the definition:

```
supernovae stars : sn supernovae stars

SELECT plainto_tsquery('supernova star');
       plainto_tsquery
-----------------------------
 'sn' & 'supernova' & 'star'
```

12.6.5. Ispell Dictionary

The Ispell dictionary template supports *morphological dictionaries*, which can normalize many different linguistic forms of a word into the same lexeme. For example, an English Ispell dictionary can match all declensions and conjugations of the search term `bank`, e.g., `banking`, `banked`, `banks`, `banks'`, and `bank's`.

The standard PostgreSQL distribution does not include any Ispell configuration files. Dictionaries for a large number of languages are available from Ispell[1]. Also, some more modern dictionary file formats are supported — MySpell[2] (OO < 2.0.1) and Hunspell[3] (OO >= 2.0.2). A large list of dictionaries is available on the OpenOffice Wiki[4].

To create an Ispell dictionary, use the built-in `ispell` template and specify several parameters:

```
CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);
```

Here, `DictFile`, `AffFile`, and `StopWords` specify the base names of the dictionary, affixes, and stop-words files. The stop-words file has the same format explained above for the `simple` dictionary type. The format of the other files is not specified here but is available from the above-mentioned web sites.

Ispell dictionaries usually recognize a limited set of words, so they should be followed by another broader dictionary; for example, a Snowball dictionary, which recognizes everything.

1. http://ficus-www.cs.ucla.edu/geoff/ispell.html
2. http://en.wikipedia.org/wiki/MySpell
3. http://sourceforge.net/projects/hunspell/
4. http://wiki.services.openoffice.org/wiki/Dictionaries

Ispell dictionaries support splitting compound words; a useful feature. Notice that the affix file should specify a special flag using the `compoundwords controlled` statement that marks dictionary words that can participate in compound formation:

```
compoundwords  controlled z
```

Here are some examples for the Norwegian language:

```
SELECT ts_lexize('norwegian_ispell', 'overbuljongterningpakkmesterassistent');
   {over,buljong,terning,pakk,mester,assistent}
SELECT ts_lexize('norwegian_ispell', 'sjokoladefabrikk');
   {sjokoladefabrikk,sjokolade,fabrikk}
```

> **Note:** MySpell does not support compound words. Hunspell has sophisticated support for compound words. At present, PostgreSQL implements only the basic compound word operations of Hunspell.

12.6.6. Snowball Dictionary

The Snowball dictionary template is based on a project by Martin Porter, inventor of the popular Porter's stemming algorithm for the English language. Snowball now provides stemming algorithms for many languages (see the Snowball site[5] for more information). Each algorithm understands how to reduce common variant forms of words to a base, or stem, spelling within its language. A Snowball dictionary requires a `language` parameter to identify which stemmer to use, and optionally can specify a `stopword` file name that gives a list of words to eliminate. (PostgreSQL's standard stopword lists are also provided by the Snowball project.) For example, there is a built-in definition equivalent to

```
CREATE TEXT SEARCH DICTIONARY english_stem (
    TEMPLATE = snowball,
    Language = english,
    StopWords = english
);
```

The stopword file format is the same as already explained.

A Snowball dictionary recognizes everything, whether or not it is able to simplify the word, so it should be placed at the end of the dictionary list. It is useless to have it before any other dictionary because a token will never pass through it to the next dictionary.

12.7. Configuration Example

A text search configuration specifies all options necessary to transform a document into a `tsvector`: the parser to use to break text into tokens, and the dictionaries to use to transform each token into a lexeme. Every call of `to_tsvector` or `to_tsquery` needs a text search configuration to perform its processing. The configuration parameter default_text_search_config specifies the name of the default

5. http://snowball.tartarus.org

configuration, which is the one used by text search functions if an explicit configuration parameter is omitted. It can be set in `postgresql.conf`, or set for an individual session using the `SET` command.

Several predefined text search configurations are available, and you can create custom configurations easily. To facilitate management of text search objects, a set of SQL commands is available, and there are several psql commands that display information about text search objects (Section 12.10).

As an example we will create a configuration `pg`, starting by duplicating the built-in `english` configuration:

```
CREATE TEXT SEARCH CONFIGURATION public.pg ( COPY = pg_catalog.english );
```

We will use a PostgreSQL-specific synonym list and store it in `$SHAREDIR/tsearch_data/pg_dict.syn`. The file contents look like:

```
postgres    pg
pgsql       pg
postgresql  pg
```

We define the synonym dictionary like this:

```
CREATE TEXT SEARCH DICTIONARY pg_dict (
    TEMPLATE = synonym,
    SYNONYMS = pg_dict
);
```

Next we register the Ispell dictionary `english_ispell`, which has its own configuration files:

```
CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);
```

Now we can set up the mappings for words in configuration `pg`:

```
ALTER TEXT SEARCH CONFIGURATION pg
    ALTER MAPPING FOR asciiword, asciihword, hword_asciipart,
                      word, hword, hword_part
    WITH pg_dict, english_ispell, english_stem;
```

We choose not to index or search some token types that the built-in configuration does handle:

```
ALTER TEXT SEARCH CONFIGURATION pg
    DROP MAPPING FOR email, url, url_path, sfloat, float;
```

Now we can test our configuration:

```
SELECT * FROM ts_debug('public.pg', '
PostgreSQL, the highly scalable, SQL compliant, open source object-relational
database management system, is now undergoing beta testing of the next
version of our software.
');
```

The next step is to set the session to use the new configuration, which was created in the public schema:

```
=> \dF
   List of text search configurations
 Schema  | Name | Description
---------+------+-------------
 public  | pg   |

SET default_text_search_config = 'public.pg';
SET

SHOW default_text_search_config;
 default_text_search_config
----------------------------
 public.pg
```

12.8. Testing and Debugging Text Search

The behavior of a custom text search configuration can easily become confusing. The functions described in this section are useful for testing text search objects. You can test a complete configuration, or test parsers and dictionaries separately.

12.8.1. Configuration Testing

The function ts_debug allows easy testing of a text search configuration.

```
ts_debug([ config regconfig, ] document text,
         OUT alias text,
         OUT description text,
         OUT token text,
         OUT dictionaries regdictionary[],
         OUT dictionary regdictionary,
         OUT lexemes text[])
         returns setof record
```

ts_debug displays information about every token of *document* as produced by the parser and processed by the configured dictionaries. It uses the configuration specified by *config*, or default_text_search_config if that argument is omitted.

ts_debug returns one row for each token identified in the text by the parser. The columns returned are

- *alias* text — short name of the token type
- *description* text — description of the token type
- *token* text — text of the token
- *dictionaries* regdictionary[] — the dictionaries selected by the configuration for this token type
- *dictionary* regdictionary — the dictionary that recognized the token, or NULL if none did
- *lexemes* text[] — the lexeme(s) produced by the dictionary that recognized the token, or NULL if none did; an empty array ({}) means it was recognized as a stop word

Here is a simple example:

```
SELECT * FROM ts_debug('english','a fat  cat sat on a mat - it ate a fat rats');
   alias   |   description   | token |  dictionaries  |  dictionary  | lexemes
-----------+-----------------+-------+----------------+--------------+---------
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | fat   | {english_stem} | english_stem | {fat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | cat   | {english_stem} | english_stem | {cat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | sat   | {english_stem} | english_stem | {sat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | on    | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | mat   | {english_stem} | english_stem | {mat}
 blank     | Space symbols   |       | {}             |              |
 blank     | Space symbols   | -     | {}             |              |
 asciiword | Word, all ASCII | it    | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | ate   | {english_stem} | english_stem | {ate}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | a     | {english_stem} | english_stem | {}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | fat   | {english_stem} | english_stem | {fat}
 blank     | Space symbols   |       | {}             |              |
 asciiword | Word, all ASCII | rats  | {english_stem} | english_stem | {rat}
```

For a more extensive demonstration, we first create a `public.english` configuration and Ispell dictionary for the English language:

```
CREATE TEXT SEARCH CONFIGURATION public.english ( COPY = pg_catalog.english );

CREATE TEXT SEARCH DICTIONARY english_ispell (
    TEMPLATE = ispell,
    DictFile = english,
    AffFile = english,
    StopWords = english
);

ALTER TEXT SEARCH CONFIGURATION public.english
   ALTER MAPPING FOR asciiword WITH english_ispell, english_stem;

SELECT * FROM ts_debug('public.english','The Brightest supernovaes');
   alias   |   description   |    token    |         dictionaries          |   dictionar
-----------+-----------------+-------------+-------------------------------+------------
 asciiword | Word, all ASCII | The         | {english_ispell,english_stem} | english_isp
 blank     | Space symbols   |             | {}                            |
 asciiword | Word, all ASCII | Brightest   | {english_ispell,english_stem} | english_isp
 blank     | Space symbols   |             | {}                            |
 asciiword | Word, all ASCII | supernovaes | {english_ispell,english_stem} | english_ste
```

In this example, the word `Brightest` was recognized by the parser as an `ASCII word` (alias `asciiword`). For this token type the dictionary list is `english_ispell` and `english_stem`. The word was recognized by `english_ispell`, which reduced it to the noun `bright`. The word `supernovaes` is unknown to the `english_ispell` dictionary so it was passed to the next dictionary, and, fortunately, was recognized (in fact, `english_stem` is a Snowball dictionary which recognizes everything; that is why it was placed at the end of the dictionary list).

The word `The` was recognized by the `english_ispell` dictionary as a stop word (Section 12.6.1) and will not be indexed. The spaces are discarded too, since the configuration provides no dictionaries at all for them.

You can reduce the width of the output by explicitly specifying which columns you want to see:

```
SELECT alias, token, dictionary, lexemes
FROM ts_debug('public.english','The Brightest supernovaes');
   alias   |    token    |   dictionary   |   lexemes
-----------+-------------+----------------+-------------
 asciiword | The         | english_ispell | {}
 blank     |             |                |
 asciiword | Brightest   | english_ispell | {bright}
 blank     |             |                |
 asciiword | supernovaes | english_stem   | {supernova}
```

12.8.2. Parser Testing

The following functions allow direct testing of a text search parser.

```
ts_parse(parser_name text, document text,
         OUT tokid integer, OUT token text) returns setof record
ts_parse(parser_oid oid, document text,
         OUT tokid integer, OUT token text) returns setof record
```

`ts_parse` parses the given *document* and returns a series of records, one for each token produced by parsing. Each record includes a `tokid` showing the assigned token type and a `token` which is the text of the token. For example:

```
SELECT * FROM ts_parse('default', '123 - a number');
 tokid | token
-------+--------
    22 | 123
    12 |
    12 | -
     1 | a
    12 |
     1 | number
```

```
ts_token_type(parser_name text, OUT tokid integer,
              OUT alias text, OUT description text) returns setof record
ts_token_type(parser_oid oid, OUT tokid integer,
              OUT alias text, OUT description text) returns setof record
```

ts_token_type returns a table which describes each type of token the specified parser can recognize. For each token type, the table gives the integer tokid that the parser uses to label a token of that type, the alias that names the token type in configuration commands, and a short description. For example:

```
SELECT * FROM ts_token_type('default');
 tokid |      alias      |               description
-------+-----------------+-----------------------------------------
     1 | asciiword       | Word, all ASCII
     2 | word            | Word, all letters
     3 | numword         | Word, letters and digits
     4 | email           | Email address
     5 | url             | URL
     6 | host            | Host
     7 | sfloat          | Scientific notation
     8 | version         | Version number
     9 | hword_numpart   | Hyphenated word part, letters and digits
    10 | hword_part      | Hyphenated word part, all letters
    11 | hword_asciipart | Hyphenated word part, all ASCII
    12 | blank           | Space symbols
    13 | tag             | XML tag
    14 | protocol        | Protocol head
    15 | numhword        | Hyphenated word, letters and digits
    16 | asciihword      | Hyphenated word, all ASCII
    17 | hword           | Hyphenated word, all letters
    18 | url_path        | URL path
    19 | file            | File or path name
    20 | float           | Decimal notation
    21 | int             | Signed integer
    22 | uint            | Unsigned integer
    23 | entity          | XML entity
```

12.8.3. Dictionary Testing

The ts_lexize function facilitates dictionary testing.

```
ts_lexize(dict regdictionary, token text) returns text[]
```

ts_lexize returns an array of lexemes if the input *token* is known to the dictionary, or an empty array if the token is known to the dictionary but it is a stop word, or NULL if it is an unknown word.

Examples:

```
SELECT ts_lexize('english_stem', 'stars');
 ts_lexize
-----------
 {star}

SELECT ts_lexize('english_stem', 'a');
 ts_lexize
-----------
 {}
```

Note: The `ts_lexize` function expects a single *token*, not text. Here is a case where this can be confusing:

```
SELECT ts_lexize('thesaurus_astro','supernovae stars') is null;
 ?column?
----------
 t
```

The thesaurus dictionary `thesaurus_astro` does know the phrase `supernovae stars`, but `ts_lexize` fails since it does not parse the input text but treats it as a single token. Use `plainto_tsquery` or `to_tsvector` to test thesaurus dictionaries, for example:

```
SELECT plainto_tsquery('supernovae stars');
 plainto_tsquery
-----------------
 'sn'
```

12.9. GiST and GIN Index Types

There are two kinds of indexes that can be used to speed up full text searches. Note that indexes are not mandatory for full text searching, but in cases where a column is searched on a regular basis, an index is usually desirable.

`CREATE INDEX` *`name`* `ON` *`table`* `USING gist(`*`column`*`);`

Creates a GiST (Generalized Search Tree)-based index. The *`column`* can be of `tsvector` or `tsquery` type.

`CREATE INDEX` *`name`* `ON` *`table`* `USING gin(`*`column`*`);`

Creates a GIN (Generalized Inverted Index)-based index. The *`column`* must be of `tsvector` type.

There are substantial performance differences between the two index types, so it is important to understand their characteristics.

A GiST index is *lossy*, meaning that the index may produce false matches, and it is necessary to check the actual table row to eliminate such false matches. (PostgreSQL does this automatically when needed.) GiST indexes are lossy because each document is represented in the index by a fixed-length signature. The signature is generated by hashing each word into a single bit in an n-bit string, with all these bits OR-ed together to produce an n-bit document signature. When two words hash to the same bit position there will be a false match. If all words in the query have matches (real or false) then the table row must be retrieved to see if the match is correct.

Lossiness causes performance degradation due to unnecessary fetches of table records that turn out to be false matches. Since random access to table records is slow, this limits the usefulness of GiST indexes. The likelihood of false matches depends on several factors, in particular the number of unique words, so using dictionaries to reduce this number is recommended.

GIN indexes are not lossy for standard queries, but their performance depends logarithmically on the number of unique words. (However, GIN indexes store only the words (lexemes) of `tsvector`

values, and not their weight labels. Thus a table row recheck is needed when using a query that involves weights.)

In choosing which index type to use, GiST or GIN, consider these performance differences:

- GIN index lookups are about three times faster than GiST
- GIN indexes take about three times longer to build than GiST
- GIN indexes are moderately slower to update than GiST indexes, but about 10 times slower if fast-update support was disabled (see Section 58.4.1 for details)
- GIN indexes are two-to-three times larger than GiST indexes

As a rule of thumb, GIN indexes are best for static data because lookups are faster. For dynamic data, GiST indexes are faster to update. Specifically, GiST indexes are very good for dynamic data and fast if the number of unique words (lexemes) is under 100,000, while GIN indexes will handle 100,000+ lexemes better but are slower to update.

Note that GIN index build time can often be improved by increasing maintenance_work_mem, while GiST index build time is not sensitive to that parameter.

Partitioning of big collections and the proper use of GiST and GIN indexes allows the implementation of very fast searches with online update. Partitioning can be done at the database level using table inheritance, or by distributing documents over servers and collecting search results using the dblink module. The latter is possible because ranking functions use only local information.

12.10. psql Support

Information about text search configuration objects can be obtained in psql using a set of commands:

```
\dF{d,p,t}[+] [PATTERN]
```

An optional + produces more details.

The optional parameter `PATTERN` can be the name of a text search object, optionally schema-qualified. If `PATTERN` is omitted then information about all visible objects will be displayed. `PATTERN` can be a regular expression and can provide *separate* patterns for the schema and object names. The following examples illustrate this:

```
=> \dF *fulltext*
       List of text search configurations
 Schema |  Name        | Description
--------+--------------+-------------
 public | fulltext_cfg |

=> \dF *.fulltext*
       List of text search configurations
 Schema   |  Name        | Description
----------+--------------+-------------
 fulltext | fulltext_cfg |
 public   | fulltext_cfg |
```

The available commands are:

```
\dF[+] [PATTERN]
```

List text search configurations (add + for more detail).

```
=> \dF russian
            List of text search configurations
   Schema   |  Name   |            Description
------------+---------+-----------------------------------
 pg_catalog | russian | configuration for russian language

=> \dF+ russian
Text search configuration "pg_catalog.russian"
Parser: "pg_catalog.default"
      Token      | Dictionaries
-----------------+--------------
 asciihword      | english_stem
 asciiword       | english_stem
 email           | simple
 file            | simple
 float           | simple
 host            | simple
 hword           | russian_stem
 hword_asciipart | english_stem
 hword_numpart   | simple
 hword_part      | russian_stem
 int             | simple
 numhword        | simple
 numword         | simple
 sfloat          | simple
 uint            | simple
 url             | simple
 url_path        | simple
 version         | simple
 word            | russian_stem
```

```
\dFd[+] [PATTERN]
```

List text search dictionaries (add + for more detail).

```
=> \dFd
                            List of text search dictionaries
   Schema   |      Name       |                        Description
------------+-----------------+-----------------------------------------------------------
 pg_catalog | danish_stem     | snowball stemmer for danish language
 pg_catalog | dutch_stem      | snowball stemmer for dutch language
 pg_catalog | english_stem    | snowball stemmer for english language
 pg_catalog | finnish_stem    | snowball stemmer for finnish language
 pg_catalog | french_stem     | snowball stemmer for french language
 pg_catalog | german_stem     | snowball stemmer for german language
 pg_catalog | hungarian_stem  | snowball stemmer for hungarian language
 pg_catalog | italian_stem    | snowball stemmer for italian language
 pg_catalog | norwegian_stem  | snowball stemmer for norwegian language
 pg_catalog | portuguese_stem | snowball stemmer for portuguese language
 pg_catalog | romanian_stem   | snowball stemmer for romanian language
 pg_catalog | russian_stem    | snowball stemmer for russian language
 pg_catalog | simple          | simple dictionary: just lower case and check for stop
 pg_catalog | spanish_stem    | snowball stemmer for spanish language
 pg_catalog | swedish_stem    | snowball stemmer for swedish language
 pg_catalog | turkish_stem    | snowball stemmer for turkish language
```

`\dFp[+] [PATTERN]`

List text search parsers (add + for more detail).

```
=> \dFp
        List of text search parsers
   Schema   |  Name   |     Description
------------+---------+---------------------
 pg_catalog | default | default word parser
=> \dFp+
    Text search parser "pg_catalog.default"
     Method      |    Function    | Description
-----------------+----------------+-------------
 Start parse     | prsd_start     |
 Get next token  | prsd_nexttoken |
 End parse       | prsd_end       |
 Get headline    | prsd_headline  |
 Get token types | prsd_lextype   |

        Token types for parser "pg_catalog.default"
   Token name    |               Description
-----------------+------------------------------------------
 asciihword      | Hyphenated word, all ASCII
 asciiword       | Word, all ASCII
 blank           | Space symbols
 email           | Email address
 entity          | XML entity
 file            | File or path name
 float           | Decimal notation
 host            | Host
 hword           | Hyphenated word, all letters
 hword_asciipart | Hyphenated word part, all ASCII
 hword_numpart   | Hyphenated word part, letters and digits
 hword_part      | Hyphenated word part, all letters
 int             | Signed integer
 numhword        | Hyphenated word, letters and digits
 numword         | Word, letters and digits
 protocol        | Protocol head
 sfloat          | Scientific notation
 tag             | XML tag
 uint            | Unsigned integer
 url             | URL
 url_path        | URL path
 version         | Version number
 word            | Word, all letters
(23 rows)
```

`\dFt[+] [PATTERN]`

List text search templates (add + for more detail).

```
=> \dFt
                            List of text search templates
   Schema   |   Name    |                        Description
------------+-----------+-----------------------------------------------------------
 pg_catalog | ispell    | ispell dictionary
 pg_catalog | simple    | simple dictionary: just lower case and check for stopword
 pg_catalog | snowball  | snowball stemmer
 pg_catalog | synonym   | synonym dictionary: replace word by its synonym
 pg_catalog | thesaurus | thesaurus dictionary: phrase by phrase substitution
```

12.11. Limitations

The current limitations of PostgreSQL's text search features are:

- The length of each lexeme must be less than 2K bytes
- The length of a `tsvector` (lexemes + positions) must be less than 1 megabyte
- The number of lexemes must be less than 2^{64}
- Position values in `tsvector` must be greater than 0 and no more than 16,383
- No more than 256 positions per lexeme
- The number of nodes (lexemes + operators) in a `tsquery` must be less than 32,768

For comparison, the PostgreSQL 8.1 documentation contained 10,441 unique words, a total of 335,420 words, and the most frequent word "postgresql" was mentioned 6,127 times in 655 documents.

Another example — the PostgreSQL mailing list archives contained 910,989 unique words with 57,491,343 lexemes in 461,020 messages.

12.12. Migration from Pre-8.3 Text Search

Applications that use the tsearch2 module for text searching will need some adjustments to work with the built-in features:

- Some functions have been renamed or had small adjustments in their argument lists, and all of them are now in the `pg_catalog` schema, whereas in a previous installation they would have been in `public` or another non-system schema. There is a new version of tsearch2 that provides a compatibility layer to solve most problems in this area.
- The old tsearch2 functions and other objects *must* be suppressed when loading pg_dump output from a pre-8.3 database. While many of them won't load anyway, a few will and then cause problems. One simple way to deal with this is to load the new tsearch2 module before restoring the dump; then it will block the old objects from being loaded.
- Text search configuration setup is completely different now. Instead of manually inserting rows into configuration tables, search is configured through the specialized SQL commands shown earlier in this chapter. There is no automated support for converting an existing custom configuration for 8.3; you're on your own here.
- Most types of dictionaries rely on some outside-the-database configuration files. These are largely compatible with pre-8.3 usage, but note the following differences:
  - Configuration files now must be placed in a single specified directory (`$SHAREDIR/tsearch_data`), and must have a specific extension depending on the type of file, as noted previously in the descriptions of the various dictionary types. This restriction was added to forestall security problems.
  - Configuration files must be encoded in UTF-8 encoding, regardless of what database encoding is used.
  - In thesaurus configuration files, stop words must be marked with `?`.

Chapter 13. Concurrency Control

This chapter describes the behavior of the PostgreSQL database system when two or more sessions try to access the same data at the same time. The goals in that situation are to allow efficient access for all sessions while maintaining strict data integrity. Every developer of database applications should be familiar with the topics covered in this chapter.

13.1. Introduction

PostgreSQL provides a rich set of tools for developers to manage concurrent access to data. Internally, data consistency is maintained by using a multiversion model (Multiversion Concurrency Control, MVCC). This means that each SQL statement sees a snapshot of data (a *database version*) as it was some time ago, regardless of the current state of the underlying data. This prevents statements from viewing inconsistent data produced by concurrent transactions performing updates on the same data rows, providing *transaction isolation* for each database session. MVCC, by eschewing the locking methodologies of traditional database systems, minimizes lock contention in order to allow for reasonable performance in multiuser environments.

The main advantage of using the MVCC model of concurrency control rather than locking is that in MVCC locks acquired for querying (reading) data do not conflict with locks acquired for writing data, and so reading never blocks writing and writing never blocks reading. PostgreSQL maintains this guarantee even when providing the strictest level of transaction isolation through the use of an innovative *Serializable Snapshot Isolation* (SSI) level.

Table- and row-level locking facilities are also available in PostgreSQL for applications which don't generally need full transaction isolation and prefer to explicitly manage particular points of conflict. However, proper use of MVCC will generally provide better performance than locks. In addition, application-defined advisory locks provide a mechanism for acquiring locks that are not tied to a single transaction.

13.2. Transaction Isolation

The SQL standard defines four levels of transaction isolation. The most strict is Serializable, which is defined by the standard in a paragraph which says that any concurrent execution of a set of Serializable transactions is guaranteed to produce the same effect as running them one at a time in some order. The other three levels are defined in terms of phenomena, resulting from interaction between concurrent transactions, which must not occur at each level. The standard notes that due to the definition of Serializable, none of these phenomena are possible at that level. (This is hardly surprising -- if the effect of the transactions must be consistent with having been run one at a time, how could you see any phenomena caused by interactions?)

The phenomena which are prohibited at various levels are:

dirty read

A transaction reads data written by a concurrent uncommitted transaction.

nonrepeatable read

A transaction re-reads data it has previously read and finds that data has been modified by another transaction (that committed since the initial read).

phantom read

A transaction re-executes a query returning a set of rows that satisfy a search condition and finds that the set of rows satisfying the condition has changed due to another recently-committed transaction.

The four transaction isolation levels and the corresponding behaviors are described in Table 13-1.

Table 13-1. Standard SQL Transaction Isolation Levels

Isolation Level	Dirty Read	Nonrepeatable Read	Phantom Read
Read uncommitted	Possible	Possible	Possible
Read committed	Not possible	Possible	Possible
Repeatable read	Not possible	Not possible	Possible
Serializable	Not possible	Not possible	Not possible

In PostgreSQL, you can request any of the four standard transaction isolation levels. But internally, there are only three distinct isolation levels, which correspond to the levels Read Committed, Repeatable Read, and Serializable. When you select the level Read Uncommitted you really get Read Committed, and phantom reads are not possible in the PostgreSQL implementation of Repeatable Read, so the actual isolation level might be stricter than what you select. This is permitted by the SQL standard: the four isolation levels only define which phenomena must not happen, they do not define which phenomena must happen. The reason that PostgreSQL only provides three isolation levels is that this is the only sensible way to map the standard isolation levels to the multiversion concurrency control architecture. The behavior of the available isolation levels is detailed in the following subsections.

To set the transaction isolation level of a transaction, use the command SET TRANSACTION.

Important: Some PostgreSQL data types and functions have special rules regarding transactional behavior. In particular, changes made to a sequence (and therefore the counter of a column declared using `serial`) are immediately visible to all other transactions and are not rolled back if the transaction that made the changes aborts. See Section 9.16 and Section 8.1.4.

13.2.1. Read Committed Isolation Level

Read Committed is the default isolation level in PostgreSQL. When a transaction uses this isolation level, a `SELECT` query (without a `FOR UPDATE/SHARE` clause) sees only data committed before the query began; it never sees either uncommitted data or changes committed during query execution by concurrent transactions. In effect, a `SELECT` query sees a snapshot of the database as of the instant the query begins to run. However, `SELECT` does see the effects of previous updates executed within its own transaction, even though they are not yet committed. Also note that two successive `SELECT` commands can see different data, even though they are within a single transaction, if other transactions commit changes after the first `SELECT` starts and before the second `SELECT` starts.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the command start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the would-be updater will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first

updater rolls back, then its effects are negated and the second updater can proceed with updating the originally found row. If the first updater commits, the second updater will ignore the row if the first updater deleted it, otherwise it will attempt to apply its operation to the updated version of the row. The search condition of the command (the `WHERE` clause) is re-evaluated to see if the updated version of the row still matches the search condition. If so, the second updater proceeds with its operation using the updated version of the row. In the case of `SELECT FOR UPDATE` and `SELECT FOR SHARE`, this means it is the updated version of the row that is locked and returned to the client.

Because of the above rule, it is possible for an updating command to see an inconsistent snapshot: it can see the effects of concurrent updating commands on the same rows it is trying to update, but it does not see effects of those commands on other rows in the database. This behavior makes Read Committed mode unsuitable for commands that involve complex search conditions; however, it is just right for simpler cases. For example, consider updating bank balances with transactions like:

```
BEGIN;
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum = 12345;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum = 7534;
COMMIT;
```

If two such transactions concurrently try to change the balance of account 12345, we clearly want the second transaction to start with the updated version of the account's row. Because each command is affecting only a predetermined row, letting it see the updated version of the row does not create any troublesome inconsistency.

More complex usage can produce undesirable results in Read Committed mode. For example, consider a `DELETE` command operating on data that is being both added and removed from its restriction criteria by another command, e.g., assume `website` is a two-row table with `website.hits` equaling `9` and `10`:

```
BEGIN;
UPDATE website SET hits = hits + 1;
-- run from another session:  DELETE FROM website WHERE hits = 10;
COMMIT;
```

The `DELETE` will have no effect even though there is a `website.hits = 10` row before and after the `UPDATE`. This occurs because the pre-update row value `9` is skipped, and when the `UPDATE` completes and `DELETE` obtains a lock, the new row value is no longer `10` but `11`, which no longer matches the criteria.

Because Read Committed mode starts each command with a new snapshot that includes all transactions committed up to that instant, subsequent commands in the same transaction will see the effects of the committed concurrent transaction in any case. The point at issue above is whether or not a *single* command sees an absolutely consistent view of the database.

The partial transaction isolation provided by Read Committed mode is adequate for many applications, and this mode is fast and simple to use; however, it is not sufficient for all cases. Applications that do complex queries and updates might require a more rigorously consistent view of the database than Read Committed mode provides.

13.2.2. Repeatable Read Isolation Level

The *Repeatable Read* isolation level only sees data committed before the transaction began; it never sees either uncommitted data or changes committed during transaction execution by concurrent transactions. (However, the query does see the effects of previous updates executed within its own transaction, even though they are not yet committed.) This is a stronger guarantee than is required by the

SQL standard for this isolation level, and prevents all of the phenomena described in Table 13-1. As mentioned above, this is specifically allowed by the standard, which only describes the *minimum* protections each isolation level must provide.

This level is different from Read Committed in that a query in a repeatable read transaction sees a snapshot as of the start of the *transaction*, not as of the start of the current query within the transaction. Thus, successive `SELECT` commands within a *single* transaction see the same data, i.e., they do not see changes made by other transactions that committed after their own transaction started.

Applications using this level must be prepared to retry transactions due to serialization failures.

`UPDATE`, `DELETE`, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` commands behave the same as `SELECT` in terms of searching for target rows: they will only find target rows that were committed as of the transaction start time. However, such a target row might have already been updated (or deleted or locked) by another concurrent transaction by the time it is found. In this case, the repeatable read transaction will wait for the first updating transaction to commit or roll back (if it is still in progress). If the first updater rolls back, then its effects are negated and the repeatable read transaction can proceed with updating the originally found row. But if the first updater commits (and actually updated or deleted the row, not just locked it) then the repeatable read transaction will be rolled back with the message

```
ERROR:  could not serialize access due to concurrent update
```

because a repeatable read transaction cannot modify or lock rows changed by other transactions after the repeatable read transaction began.

When an application receives this error message, it should abort the current transaction and retry the whole transaction from the beginning. The second time through, the transaction will see the previously-committed change as part of its initial view of the database, so there is no logical conflict in using the new version of the row as the starting point for the new transaction's update.

Note that only updating transactions might need to be retried; read-only transactions will never have serialization conflicts.

The Repeatable Read mode provides a rigorous guarantee that each transaction sees a completely stable view of the database. However, this view will not necessarily always be consistent with some serial (one at a time) execution of concurrent transactions of the same level. For example, even a read only transaction at this level may see a control record updated to show that a batch has been completed but *not* see one of the detail records which is logically part of the batch because it read an earlier revision of the control record. Attempts to enforce business rules by transactions running at this isolation level are not likely to work correctly without careful use of explicit locks to block conflicting transactions.

> **Note:** Prior to PostgreSQL version 9.1, a request for the Serializable transaction isolation level provided exactly the same behavior described here. To retain the legacy Serializable behavior, Repeatable Read should now be requested.

13.2.3. Serializable Isolation Level

The *Serializable* isolation level provides the strictest transaction isolation. This level emulates serial transaction execution for all committed transactions; as if transactions had been executed one after another, serially, rather than concurrently. However, like the Repeatable Read level, applications using this level must be prepared to retry transactions due to serialization failures. In fact, this isolation level

works exactly the same as Repeatable Read except that it monitors for conditions which could make execution of a concurrent set of serializable transactions behave in a manner inconsistent with all possible serial (one at a time) executions of those transactions. This monitoring does not introduce any blocking beyond that present in repeatable read, but there is some overhead to the monitoring, and detection of the conditions which could cause a *serialization anomaly* will trigger a *serialization failure*.

As an example, consider a table `mytab`, initially containing:

```
 class | value
-------+-------
     1 |    10
     1 |    20
     2 |   100
     2 |   200
```

Suppose that serializable transaction A computes:

```
SELECT SUM(value) FROM mytab WHERE class = 1;
```

and then inserts the result (30) as the `value` in a new row with `class = 2`. Concurrently, serializable transaction B computes:

```
SELECT SUM(value) FROM mytab WHERE class = 2;
```

and obtains the result 300, which it inserts in a new row with `class = 1`. Then both transactions try to commit. If either transaction were running at the Repeatable Read isolation level, both would be allowed to commit; but since there is no serial order of execution consistent with the result, using Serializable transactions will allow one transaction to commit and will roll the other back with this message:

```
ERROR:  could not serialize access due to read/write dependencies among transactions
```

This is because if A had executed before B, B would have computed the sum 330, not 300, and similarly the other order would have resulted in a different sum computed by A.

When relying on Serializable transactions to prevent anomalies, it is important that any data read from a permanent user table not be considered valid until the transaction which read it has successfully committed. This is true even for read-only transactions, except that data read within a *deferrable* read-only transaction is known to be valid as soon as it is read, because such a transaction waits until it can acquire a snapshot guaranteed to be free from such problems before starting to read any data. In all other cases applications must not depend on results read during a transaction that later aborted; instead, they should retry the transaction until it succeeds.

To guarantee true serializability PostgreSQL uses *predicate locking*, which means that it keeps locks which allow it to determine when a write would have had an impact on the result of a previous read from a concurrent transaction, had it run first. In PostgreSQL these locks do not cause any blocking and therefore can *not* play any part in causing a deadlock. They are used to identify and flag dependencies among concurrent serializable transactions which in certain combinations can lead to serialization anomalies. In contrast, a Read Committed or Repeatable Read transaction which wants to ensure data consistency may need to take out a lock on an entire table, which could block other users attempting to use that table, or it may use `SELECT FOR UPDATE` or `SELECT FOR SHARE` which not only can block other transactions but cause disk access.

Predicate locks in PostgreSQL, like in most other database systems, are based on data actually accessed by a transaction. These will show up in the `pg_locks` system view with a `mode` of `SIReadLock`. The particular locks acquired during execution of a query will depend on the plan

used by the query, and multiple finer-grained locks (e.g., tuple locks) may be combined into fewer coarser-grained locks (e.g., page locks) during the course of the transaction to prevent exhaustion of the memory used to track the locks. A `READ ONLY` transaction may be able to release its SIRead locks before completion, if it detects that no conflicts can still occur which could lead to a serialization anomaly. In fact, `READ ONLY` transactions will often be able to establish that fact at startup and avoid taking any predicate locks. If you explicitly request a `SERIALIZABLE READ ONLY DEFERRABLE` transaction, it will block until it can establish this fact. (This is the *only* case where Serializable transactions block but Repeatable Read transactions don't.) On the other hand, SIRead locks often need to be kept past transaction commit, until overlapping read write transactions complete.

Consistent use of Serializable transactions can simplify development. The guarantee that any set of concurrent serializable transactions will have the same effect as if they were run one at a time means that if you can demonstrate that a single transaction, as written, will do the right thing when run by itself, you can have confidence that it will do the right thing in any mix of serializable transactions, even without any information about what those other transactions might do. It is important that an environment which uses this technique have a generalized way of handling serialization failures (which always return with a SQLSTATE value of '40001'), because it will be very hard to predict exactly which transactions might contribute to the read/write dependencies and need to be rolled back to prevent serialization anomalies. The monitoring of read/write dependencies has a cost, as does the restart of transactions which are terminated with a serialization failure, but balanced against the cost and blocking involved in use of explicit locks and `SELECT FOR UPDATE` or `SELECT FOR SHARE`, Serializable transactions are the best performance choice for some environments.

For optimal performance when relying on Serializable transactions for concurrency control, these issues should be considered:

- Declare transactions as `READ ONLY` when possible.
- Control the number of active connections, using a connection pool if needed. This is always an important performance consideration, but it can be particularly important in a busy system using Serializable transactions.
- Don't put more into a single transaction than needed for integrity purposes.
- Don't leave connections dangling "idle in transaction" longer than necessary.
- Eliminate explicit locks, `SELECT FOR UPDATE`, and `SELECT FOR SHARE` where no longer needed due to the protections automatically provided by Serializable transactions.
- When the system is forced to combine multiple page-level predicate locks into a single relation-level predicate lock because the predicate lock table is short of memory, an increase in the rate of serialization failures may occur. You can avoid this by increasing max_pred_locks_per_transaction.
- A sequential scan will always necessitate a relation-level predicate lock. This can result in an increased rate of serialization failures. It may be helpful to encourage the use of index scans by reducing random_page_cost and/or increasing cpu_tuple_cost. Be sure to weigh any decrease in transaction rollbacks and restarts against any overall change in query execution time.

Warning

Support for the Serializable transaction isolation level has not yet been added to Hot Standby replication targets (described in Section 25.5). The strictest isolation level currently supported in hot standby mode is Repeatable Read. While performing all permanent database writes within Serializable transactions on the master will ensure that all standbys will eventually reach a consistent state, a Repeatable Read transaction run on the standby can sometimes see a transient state which is inconsistent with any serial execution of serializable transactions on the master.

13.3. Explicit Locking

PostgreSQL provides various lock modes to control concurrent access to data in tables. These modes can be used for application-controlled locking in situations where MVCC does not give the desired behavior. Also, most PostgreSQL commands automatically acquire locks of appropriate modes to ensure that referenced tables are not dropped or modified in incompatible ways while the command executes. (For example, `TRUNCATE` cannot safely be executed concurrently with other operations on the same table, so it obtains an exclusive lock on the table to enforce that.)

To examine a list of the currently outstanding locks in a database server, use the `pg_locks` system view. For more information on monitoring the status of the lock manager subsystem, refer to Chapter 27.

13.3.1. Table-level Locks

The list below shows the available lock modes and the contexts in which they are used automatically by PostgreSQL. You can also acquire any of these locks explicitly with the command LOCK. Remember that all of these lock modes are table-level locks, even if the name contains the word "row"; the names of the lock modes are historical. To some extent the names reflect the typical usage of each lock mode — but the semantics are all the same. The only real difference between one lock mode and another is the set of lock modes with which each conflicts (see Table 13-2). Two transactions cannot hold locks of conflicting modes on the same table at the same time. (However, a transaction never conflicts with itself. For example, it might acquire `ACCESS EXCLUSIVE` lock and later acquire `ACCESS SHARE` lock on the same table.) Non-conflicting lock modes can be held concurrently by many transactions. Notice in particular that some lock modes are self-conflicting (for example, an `ACCESS EXCLUSIVE` lock cannot be held by more than one transaction at a time) while others are not self-conflicting (for example, an `ACCESS SHARE` lock can be held by multiple transactions).

Table-level Lock Modes

`ACCESS SHARE`

Conflicts with the `ACCESS EXCLUSIVE` lock mode only.

The `SELECT` command acquires a lock of this mode on referenced tables. In general, any query that only *reads* a table and does not modify it will acquire this lock mode.

`ROW SHARE`

Conflicts with the `EXCLUSIVE` and `ACCESS EXCLUSIVE` lock modes.

The SELECT FOR UPDATE and SELECT FOR SHARE commands acquire a lock of this mode on the target table(s) (in addition to ACCESS SHARE locks on any other tables that are referenced but not selected FOR UPDATE/FOR SHARE).

ROW EXCLUSIVE

Conflicts with the SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes.

The commands UPDATE, DELETE, and INSERT acquire this lock mode on the target table (in addition to ACCESS SHARE locks on any other referenced tables). In general, this lock mode will be acquired by any command that *modifies data* in a table.

SHARE UPDATE EXCLUSIVE

Conflicts with the SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent schema changes and VACUUM runs.

Acquired by VACUUM (without FULL), ANALYZE, CREATE INDEX CONCURRENTLY, and ALTER TABLE VALIDATE and other ALTER TABLE variants (for full details see ALTER TABLE).

SHARE

Conflicts with the ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent data changes.

Acquired by CREATE INDEX (without CONCURRENTLY).

SHARE ROW EXCLUSIVE

Conflicts with the ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode protects a table against concurrent data changes, and is self-exclusive so that only one session can hold it at a time.

This lock mode is not automatically acquired by any PostgreSQL command.

EXCLUSIVE

Conflicts with the ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE lock modes. This mode allows only concurrent ACCESS SHARE locks, i.e., only reads from the table can proceed in parallel with a transaction holding this lock mode.

Acquired by REFRESH MATERIALIZED VIEW CONCURRENTLY.

ACCESS EXCLUSIVE

Conflicts with locks of all modes (ACCESS SHARE, ROW SHARE, ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, and ACCESS EXCLUSIVE). This mode guarantees that the holder is the only transaction accessing the table in any way.

Acquired by the DROP TABLE, TRUNCATE, REINDEX, CLUSTER, and VACUUM FULL commands. Many forms of ALTER TABLE also acquire a lock at this level (see ALTER TABLE). This is also the default lock mode for LOCK TABLE statements that do not specify a mode explicitly.

Tip: Only an ACCESS EXCLUSIVE lock blocks a SELECT (without FOR UPDATE/SHARE) statement.

Once acquired, a lock is normally held till end of transaction. But if a lock is acquired after establishing a savepoint, the lock is released immediately if the savepoint is rolled back to. This is consistent with the principle that `ROLLBACK` cancels all effects of the commands since the savepoint. The same holds for locks acquired within a PL/pgSQL exception block: an error escape from the block releases locks acquired within it.

Table 13-2. Conflicting Lock Modes

Requested Lock Mode	Current Lock Mode							
	ACCESS SHARE	ROW SHARE	ROW EXCLUSIVE	SHARE UPDATE EXCLUSIVE	SHARE	SHARE ROW EXCLUSIVE	EXCLUSIVE	ACCESS EXCLUSIVE
ACCESS SHARE								X
ROW SHARE							X	X
ROW EXCLUSIVE					X	X	X	X
SHARE UPDATE EXCLUSIVE				X	X	X	X	X
SHARE			X	X		X	X	X
SHARE ROW EXCLUSIVE			X	X	X	X	X	X
EXCLUSIVE		X	X	X	X	X	X	X
ACCESS EXCLUSIVE	X	X	X	X	X	X	X	X

13.3.2. Row-level Locks

In addition to table-level locks, there are row-level locks, which are listed as below with the contexts in which they are used automatically by PostgreSQL. See Table 13-3 for a complete table of row-level lock conflicts. Note that a transaction can hold conflicting locks on the same row, even in different subtransactions; but other than that, two transactions can never hold conflicting locks on the same row. Row-level locks do not affect data querying; they block only *writers and lockers* to the same row.

Row-level Lock Modes

`FOR UPDATE`

`FOR UPDATE` causes the rows retrieved by the `SELECT` statement to be locked as though for update. This prevents them from being locked, modified or deleted by other transactions until the current transaction ends. That is, other transactions that attempt `UPDATE`, `DELETE`, `SELECT FOR UPDATE`, `SELECT FOR NO KEY UPDATE`, `SELECT FOR SHARE` or `SELECT FOR KEY SHARE` of these rows will be blocked until the current transaction ends; conversely, `SELECT FOR UPDATE` will wait for a concurrent transaction that has run any of those commands on the same row, and will then lock and return the updated row (or no row, if the row was deleted). Within a `REPEATABLE READ` or `SERIALIZABLE` transaction, however, an error will be thrown if a row to be locked has changed since the transaction started. For further discussion see Section 13.4.

The `FOR UPDATE` lock mode is also acquired by any `DELETE` on a row, and also by an `UPDATE` that modifies the values on certain columns. Currently, the set of columns considered for the `UPDATE` case are those that have a unique index on them that can be used in a foreign key (so partial indexes and expressional indexes are not considered), but this may change in the future.

`FOR NO KEY UPDATE`

Behaves similarly to `FOR UPDATE`, except that the lock acquired is weaker: this lock will not block `SELECT FOR KEY SHARE` commands that attempt to acquire a lock on the same rows. This lock mode is also acquired by any `UPDATE` that does not acquire a `FOR UPDATE` lock.

`FOR SHARE`

Behaves similarly to `FOR NO KEY UPDATE`, except that it acquires a shared lock rather than exclusive lock on each retrieved row. A shared lock blocks other transactions from performing `UPDATE`, `DELETE`, `SELECT FOR UPDATE` or `SELECT FOR NO KEY UPDATE` on these rows, but it does not prevent them from performing `SELECT FOR SHARE` or `SELECT FOR KEY SHARE`.

`FOR KEY SHARE`

Behaves similarly to `FOR SHARE`, except that the lock is weaker: `SELECT FOR UPDATE` is blocked, but not `SELECT FOR NO KEY UPDATE`. A key-shared lock blocks other transactions from performing `DELETE` or any `UPDATE` that changes the key values, but not other `UPDATE`, and neither does it prevent `SELECT FOR NO KEY UPDATE`, `SELECT FOR SHARE`, or `SELECT FOR KEY SHARE`.

PostgreSQL doesn't remember any information about modified rows in memory, so there is no limit on the number of rows locked at one time. However, locking a row might cause a disk write, e.g., `SELECT FOR UPDATE` modifies selected rows to mark them locked, and so will result in disk writes.

Table 13-3. Conflicting Row-level Locks

Requested Lock Mode	Current Lock Mode			
	FOR KEY SHARE	FOR SHARE	FOR NO KEY UPDATE	FOR UPDATE
FOR KEY SHARE				X
FOR SHARE			X	X
FOR NO KEY UPDATE		X	X	X

Requested Lock Mode	Current Lock Mode			
	FOR KEY SHARE	FOR SHARE	FOR NO KEY UPDATE	FOR UPDATE
FOR UPDATE	X	X	X	X

13.3.3. Page-level Locks

In addition to table and row locks, page-level share/exclusive locks are used to control read/write access to table pages in the shared buffer pool. These locks are released immediately after a row is fetched or updated. Application developers normally need not be concerned with page-level locks, but they are mentioned here for completeness.

13.3.4. Deadlocks

The use of explicit locking can increase the likelihood of *deadlocks*, wherein two (or more) transactions each hold locks that the other wants. For example, if transaction 1 acquires an exclusive lock on table A and then tries to acquire an exclusive lock on table B, while transaction 2 has already exclusive-locked table B and now wants an exclusive lock on table A, then neither one can proceed. PostgreSQL automatically detects deadlock situations and resolves them by aborting one of the transactions involved, allowing the other(s) to complete. (Exactly which transaction will be aborted is difficult to predict and should not be relied upon.)

Note that deadlocks can also occur as the result of row-level locks (and thus, they can occur even if explicit locking is not used). Consider the case in which two concurrent transactions modify a table. The first transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum = 11111;
```

This acquires a row-level lock on the row with the specified account number. Then, the second transaction executes:

```
UPDATE accounts SET balance = balance + 100.00 WHERE acctnum = 22222;
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum = 11111;
```

The first `UPDATE` statement successfully acquires a row-level lock on the specified row, so it succeeds in updating that row. However, the second `UPDATE` statement finds that the row it is attempting to update has already been locked, so it waits for the transaction that acquired the lock to complete. Transaction two is now waiting on transaction one to complete before it continues execution. Now, transaction one executes:

```
UPDATE accounts SET balance = balance - 100.00 WHERE acctnum = 22222;
```

Transaction one attempts to acquire a row-level lock on the specified row, but it cannot: transaction two already holds such a lock. So it waits for transaction two to complete. Thus, transaction one is blocked on transaction two, and transaction two is blocked on transaction one: a deadlock condition. PostgreSQL will detect this situation and abort one of the transactions.

The best defense against deadlocks is generally to avoid them by being certain that all applications using a database acquire locks on multiple objects in a consistent order. In the example above, if both transactions had updated the rows in the same order, no deadlock would have occurred. One should also ensure that the first lock acquired on an object in a transaction is the most restrictive mode that

will be needed for that object. If it is not feasible to verify this in advance, then deadlocks can be handled on-the-fly by retrying transactions that abort due to deadlocks.

So long as no deadlock situation is detected, a transaction seeking either a table-level or row-level lock will wait indefinitely for conflicting locks to be released. This means it is a bad idea for applications to hold transactions open for long periods of time (e.g., while waiting for user input).

13.3.5. Advisory Locks

PostgreSQL provides a means for creating locks that have application-defined meanings. These are called *advisory locks*, because the system does not enforce their use — it is up to the application to use them correctly. Advisory locks can be useful for locking strategies that are an awkward fit for the MVCC model. For example, a common use of advisory locks is to emulate pessimistic locking strategies typical of so-called "flat file" data management systems. While a flag stored in a table could be used for the same purpose, advisory locks are faster, avoid table bloat, and are automatically cleaned up by the server at the end of the session.

There are two ways to acquire an advisory lock in PostgreSQL: at session level or at transaction level. Once acquired at session level, an advisory lock is held until explicitly released or the session ends. Unlike standard lock requests, session-level advisory lock requests do not honor transaction semantics: a lock acquired during a transaction that is later rolled back will still be held following the rollback, and likewise an unlock is effective even if the calling transaction fails later. A lock can be acquired multiple times by its owning process; for each completed lock request there must be a corresponding unlock request before the lock is actually released. Transaction-level lock requests, on the other hand, behave more like regular lock requests: they are automatically released at the end of the transaction, and there is no explicit unlock operation. This behavior is often more convenient than the session-level behavior for short-term usage of an advisory lock. Session-level and transaction-level lock requests for the same advisory lock identifier will block each other in the expected way. If a session already holds a given advisory lock, additional requests by it will always succeed, even if other sessions are awaiting the lock; this statement is true regardless of whether the existing lock hold and new request are at session level or transaction level.

Like all locks in PostgreSQL, a complete list of advisory locks currently held by any session can be found in the `pg_locks` system view.

Both advisory locks and regular locks are stored in a shared memory pool whose size is defined by the configuration variables max_locks_per_transaction and max_connections. Care must be taken not to exhaust this memory or the server will be unable to grant any locks at all. This imposes an upper limit on the number of advisory locks grantable by the server, typically in the tens to hundreds of thousands depending on how the server is configured.

In certain cases using advisory locking methods, especially in queries involving explicit ordering and `LIMIT` clauses, care must be taken to control the locks acquired because of the order in which SQL expressions are evaluated. For example:

```
SELECT pg_advisory_lock(id) FROM foo WHERE id = 12345; -- ok
SELECT pg_advisory_lock(id) FROM foo WHERE id > 12345 LIMIT 100; -- danger!
SELECT pg_advisory_lock(q.id) FROM
(
  SELECT id FROM foo WHERE id > 12345 LIMIT 100
) q; -- ok
```

In the above queries, the second form is dangerous because the `LIMIT` is not guaranteed to be applied before the locking function is executed. This might cause some locks to be acquired that the applica-

tion was not expecting, and hence would fail to release (until it ends the session). From the point of view of the application, such locks would be dangling, although still viewable in `pg_locks`.

The functions provided to manipulate advisory locks are described in Section 9.26.9.

13.4. Data Consistency Checks at the Application Level

It is very difficult to enforce business rules regarding data integrity using Read Committed transactions because the view of the data is shifting with each statement, and even a single statement may not restrict itself to the statement's snapshot if a write conflict occurs.

While a Repeatable Read transaction has a stable view of the data throughout its execution, there is a subtle issue with using MVCC snapshots for data consistency checks, involving something known as *read/write conflicts*. If one transaction writes data and a concurrent transaction attempts to read the same data (whether before or after the write), it cannot see the work of the other transaction. The reader then appears to have executed first regardless of which started first or which committed first. If that is as far as it goes, there is no problem, but if the reader also writes data which is read by a concurrent transaction there is now a transaction which appears to have run before either of the previously mentioned transactions. If the transaction which appears to have executed last actually commits first, it is very easy for a cycle to appear in a graph of the order of execution of the transactions. When such a cycle appears, integrity checks will not work correctly without some help.

As mentioned in Section 13.2.3, Serializable transactions are just Repeatable Read transactions which add nonblocking monitoring for dangerous patterns of read/write conflicts. When a pattern is detected which could cause a cycle in the apparent order of execution, one of the transactions involved is rolled back to break the cycle.

13.4.1. Enforcing Consistency With Serializable Transactions

If the Serializable transaction isolation level is used for all writes and for all reads which need a consistent view of the data, no other effort is required to ensure consistency. Software from other environments which is written to use serializable transactions to ensure consistency should "just work" in this regard in PostgreSQL.

When using this technique, it will avoid creating an unnecessary burden for application programmers if the application software goes through a framework which automatically retries transactions which are rolled back with a serialization failure. It may be a good idea to set `default_transaction_isolation` to `serializable`. It would also be wise to take some action to ensure that no other transaction isolation level is used, either inadvertently or to subvert integrity checks, through checks of the transaction isolation level in triggers.

See Section 13.2.3 for performance suggestions.

Warning

This level of integrity protection using Serializable transactions does not yet extend to hot standby mode (Section 25.5). Because of that, those using hot standby may want to use Repeatable Read and explicit locking.on the master.

13.4.2. Enforcing Consistency With Explicit Blocking Locks

When non-serializable writes are possible, to ensure the current validity of a row and protect it against concurrent updates one must use SELECT FOR UPDATE, SELECT FOR SHARE, or an appropriate LOCK TABLE statement. (SELECT FOR UPDATE and SELECT FOR SHARE lock just the returned rows against concurrent updates, while LOCK TABLE locks the whole table.) This should be taken into account when porting applications to PostgreSQL from other environments.

Also of note to those converting from other environments is the fact that SELECT FOR UPDATE does not ensure that a concurrent transaction will not update or delete a selected row. To do that in PostgreSQL you must actually update the row, even if no values need to be changed. SELECT FOR UPDATE *temporarily blocks* other transactions from acquiring the same lock or executing an UPDATE or DELETE which would affect the locked row, but once the transaction holding this lock commits or rolls back, a blocked transaction will proceed with the conflicting operation unless an actual UPDATE of the row was performed while the lock was held.

Global validity checks require extra thought under non-serializable MVCC. For example, a banking application might wish to check that the sum of all credits in one table equals the sum of debits in another table, when both tables are being actively updated. Comparing the results of two successive SELECT sum(...) commands will not work reliably in Read Committed mode, since the second query will likely include the results of transactions not counted by the first. Doing the two sums in a single repeatable read transaction will give an accurate picture of only the effects of transactions that committed before the repeatable read transaction started — but one might legitimately wonder whether the answer is still relevant by the time it is delivered. If the repeatable read transaction itself applied some changes before trying to make the consistency check, the usefulness of the check becomes even more debatable, since now it includes some but not all post-transaction-start changes. In such cases a careful person might wish to lock all tables needed for the check, in order to get an indisputable picture of current reality. A SHARE mode (or higher) lock guarantees that there are no uncommitted changes in the locked table, other than those of the current transaction.

Note also that if one is relying on explicit locking to prevent concurrent changes, one should either use Read Committed mode, or in Repeatable Read mode be careful to obtain locks before performing queries. A lock obtained by a repeatable read transaction guarantees that no other transactions modifying the table are still running, but if the snapshot seen by the transaction predates obtaining the lock, it might predate some now-committed changes in the table. A repeatable read transaction's snapshot is actually frozen at the start of its first query or data-modification command (SELECT, INSERT, UPDATE, or DELETE), so it is possible to obtain locks explicitly before the snapshot is frozen.

13.5. Locking and Indexes

Though PostgreSQL provides nonblocking read/write access to table data, nonblocking read/write access is not currently offered for every index access method implemented in PostgreSQL. The various index types are handled as follows:

B-tree, GiST and SP-GiST indexes

: Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. These index types provide the highest concurrency without deadlock conditions.

Hash indexes

: Share/exclusive hash-bucket-level locks are used for read/write access. Locks are released after

the whole bucket is processed. Bucket-level locks provide better concurrency than index-level ones, but deadlock is possible since the locks are held longer than one index operation.

GIN indexes

Short-term share/exclusive page-level locks are used for read/write access. Locks are released immediately after each index row is fetched or inserted. But note that insertion of a GIN-indexed value usually produces several index key insertions per row, so GIN might do substantial work for a single value's insertion.

Currently, B-tree indexes offer the best performance for concurrent applications; since they also have more features than hash indexes, they are the recommended index type for concurrent applications that need to index scalar data. When dealing with non-scalar data, B-trees are not useful, and GiST, SP-GiST or GIN indexes should be used instead.

Chapter 14. Performance Tips

Query performance can be affected by many things. Some of these can be controlled by the user, while others are fundamental to the underlying design of the system. This chapter provides some hints about understanding and tuning PostgreSQL performance.

14.1. Using EXPLAIN

PostgreSQL devises a *query plan* for each query it receives. Choosing the right plan to match the query structure and the properties of the data is absolutely critical for good performance, so the system includes a complex *planner* that tries to choose good plans. You can use the EXPLAIN command to see what query plan the planner creates for any query. Plan-reading is an art that requires some experience to master, but this section attempts to cover the basics.

Examples in this section are drawn from the regression test database after doing a VACUUM ANALYZE, using 9.3 development sources. You should be able to get similar results if you try the examples yourself, but your estimated costs and row counts might vary slightly because ANALYZE's statistics are random samples rather than exact, and because costs are inherently somewhat platform-dependent.

The examples use EXPLAIN's default "text" output format, which is compact and convenient for humans to read. If you want to feed EXPLAIN's output to a program for further analysis, you should use one of its machine-readable output formats (XML, JSON, or YAML) instead.

14.1.1. EXPLAIN Basics

The structure of a query plan is a tree of *plan nodes*. Nodes at the bottom level of the tree are scan nodes: they return raw rows from a table. There are different types of scan nodes for different table access methods: sequential scans, index scans, and bitmap index scans. There are also non-table row sources, such as VALUES clauses and set-returning functions in FROM, which have their own scan node types. If the query requires joining, aggregation, sorting, or other operations on the raw rows, then there will be additional nodes above the scan nodes to perform these operations. Again, there is usually more than one possible way to do these operations, so different node types can appear here too. The output of EXPLAIN has one line for each node in the plan tree, showing the basic node type plus the cost estimates that the planner made for the execution of that plan node. Additional lines might appear, indented from the node's summary line, to show additional properties of the node. The very first line (the summary line for the topmost node) has the estimated total execution cost for the plan; it is this number that the planner seeks to minimize.

Here is a trivial example, just to show what the output looks like:

```
EXPLAIN SELECT * FROM tenk1;

                        QUERY PLAN
-------------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

Since this query has no WHERE clause, it must scan all the rows of the table, so the planner has chosen to use a simple sequential scan plan. The numbers that are quoted in parentheses are (left to right):

- Estimated start-up cost. This is the time expended before the output phase can begin, e.g., time to do the sorting in a sort node.
- Estimated total cost. This is stated on the assumption that the plan node is run to completion, i.e., all available rows are retrieved. In practice a node's parent node might stop short of reading all available rows (see the `LIMIT` example below).
- Estimated number of rows output by this plan node. Again, the node is assumed to be run to completion.
- Estimated average width of rows output by this plan node (in bytes).

The costs are measured in arbitrary units determined by the planner's cost parameters (see Section 18.7.2). Traditional practice is to measure the costs in units of disk page fetches; that is, seq_page_cost is conventionally set to `1.0` and the other cost parameters are set relative to that. The examples in this section are run with the default cost parameters.

It's important to understand that the cost of an upper-level node includes the cost of all its child nodes. It's also important to realize that the cost only reflects things that the planner cares about. In particular, the cost does not consider the time spent transmitting result rows to the client, which could be an important factor in the real elapsed time; but the planner ignores it because it cannot change it by altering the plan. (Every correct plan will output the same row set, we trust.)

The `rows` value is a little tricky because it is not the number of rows processed or scanned by the plan node, but rather the number emitted by the node. This is often less than the number scanned, as a result of filtering by any `WHERE`-clause conditions that are being applied at the node. Ideally the top-level rows estimate will approximate the number of rows actually returned, updated, or deleted by the query.

Returning to our example:

```
EXPLAIN SELECT * FROM tenk1;

                         QUERY PLAN
-------------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

These numbers are derived very straightforwardly. If you do:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';
```

you will find that `tenk1` has 358 disk pages and 10000 rows. The estimated cost is computed as (disk pages read * seq_page_cost) + (rows scanned * cpu_tuple_cost). By default, `seq_page_cost` is 1.0 and `cpu_tuple_cost` is 0.01, so the estimated cost is (358 * 1.0) + (10000 * 0.01) = 458.

Now let's modify the query to add a `WHERE` condition:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 7000;

                         QUERY PLAN
------------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..483.00 rows=7001 width=244)
   Filter: (unique1 < 7000)
```

Notice that the `EXPLAIN` output shows the `WHERE` clause being applied as a "filter" condition attached to the Seq Scan plan node. This means that the plan node checks the condition for each row it scans,

and outputs only the ones that pass the condition. The estimate of output rows has been reduced because of the WHERE clause. However, the scan will still have to visit all 10000 rows, so the cost hasn't decreased; in fact it has gone up a bit (by 10000 * cpu_operator_cost, to be exact) to reflect the extra CPU time spent checking the WHERE condition.

The actual number of rows this query would select is 7000, but the rows estimate is only approximate. If you try to duplicate this experiment, you will probably get a slightly different estimate; moreover, it can change after each ANALYZE command, because the statistics produced by ANALYZE are taken from a randomized sample of the table.

Now, let's make the condition more restrictive:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100;

                                     QUERY PLAN
-------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=5.07..229.20 rows=101 width=244)
   Recheck Cond: (unique1 < 100)
   ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0)
         Index Cond: (unique1 < 100)
```

Here the planner has decided to use a two-step plan: the child plan node visits an index to find the locations of rows matching the index condition, and then the upper plan node actually fetches those rows from the table itself. Fetching rows separately is much more expensive than reading them sequentially, but because not all the pages of the table have to be visited, this is still cheaper than a sequential scan. (The reason for using two plan levels is that the upper plan node sorts the row locations identified by the index into physical order before reading them, to minimize the cost of separate fetches. The "bitmap" mentioned in the node names is the mechanism that does the sorting.)

Now let's add another condition to the WHERE clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND stringu1 = 'xxx';

                                     QUERY PLAN
-------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=5.04..229.43 rows=1 width=244)
   Recheck Cond: (unique1 < 100)
   Filter: (stringu1 = 'xxx'::name)
   ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0)
         Index Cond: (unique1 < 100)
```

The added condition stringu1 = 'xxx' reduces the output row count estimate, but not the cost because we still have to visit the same set of rows. Notice that the stringu1 clause cannot be applied as an index condition, since this index is only on the unique1 column. Instead it is applied as a filter on the rows retrieved by the index. Thus the cost has actually gone up slightly to reflect this extra checking.

In some cases the planner will prefer a "simple" index scan plan:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 = 42;

                                     QUERY PLAN
-------------------------------------------------------------------------------
 Index Scan using tenk1_unique1 on tenk1  (cost=0.29..8.30 rows=1 width=244)
   Index Cond: (unique1 = 42)
```

In this type of plan the table rows are fetched in index order, which makes them even more expensive to read, but there are so few that the extra cost of sorting the row locations is not worth it. You'll most

often see this plan type for queries that fetch just a single row. It's also often used for queries that have an ORDER BY condition that matches the index order, because then no extra sorting step is needed to satisfy the ORDER BY.

If there are separate indexes on several of the columns referenced in WHERE, the planner might choose to use an AND or OR combination of the indexes:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000;

                                     QUERY PLAN
-------------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=25.08..60.21 rows=10 width=244)
   Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
   ->  BitmapAnd  (cost=25.08..25.08 rows=10 width=0)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0)
               Index Cond: (unique1 < 100)
         ->  Bitmap Index Scan on tenk1_unique2  (cost=0.00..19.78 rows=999 width=0)
               Index Cond: (unique2 > 9000)
```

But this requires visiting both indexes, so it's not necessarily a win compared to using just one index and treating the other condition as a filter. If you vary the ranges involved you'll see the plan change accordingly.

Here is an example showing the effects of LIMIT:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000 LIMIT 2;

                                     QUERY PLAN
-------------------------------------------------------------------------------------
 Limit  (cost=0.29..14.48 rows=2 width=244)
   ->  Index Scan using tenk1_unique2 on tenk1  (cost=0.29..71.27 rows=10 width=244)
         Index Cond: (unique2 > 9000)
         Filter: (unique1 < 100)
```

This is the same query as above, but we added a LIMIT so that not all the rows need be retrieved, and the planner changed its mind about what to do. Notice that the total cost and row count of the Index Scan node are shown as if it were run to completion. However, the Limit node is expected to stop after retrieving only a fifth of those rows, so its total cost is only a fifth as much, and that's the actual estimated cost of the query. This plan is preferred over adding a Limit node to the previous plan because the Limit could not avoid paying the startup cost of the bitmap scan, so the total cost would be something over 25 units with that approach.

Let's try joining two tables, using the columns we have been discussing:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;

                                      QUERY PLAN
--------------------------------------------------------------------------------------
 Nested Loop  (cost=4.65..118.62 rows=10 width=488)
   ->  Bitmap Heap Scan on tenk1 t1  (cost=4.36..39.47 rows=10 width=244)
         Recheck Cond: (unique1 < 10)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..4.36 rows=10 width=0)
               Index Cond: (unique1 < 10)
   ->  Index Scan using tenk2_unique2 on tenk2 t2  (cost=0.29..7.91 rows=1 width=244)
```

```
         Index Cond: (unique2 = t1.unique2)
```

In this plan, we have a nested-loop join node with two table scans as inputs, or children. The indentation of the node summary lines reflects the plan tree structure. The join's first, or "outer", child is a bitmap scan similar to those we saw before. Its cost and row count are the same as we'd get from `SELECT ... WHERE unique1 < 10` because we are applying the `WHERE` clause `unique1 < 10` at that node. The `t1.unique2 = t2.unique2` clause is not relevant yet, so it doesn't affect the row count of the outer scan. The nested-loop join node will run its second, or "inner" child once for each row obtained from the outer child. Column values from the current outer row can be plugged into the inner scan; here, the `t1.unique2` value from the outer row is available, so we get a plan and costs similar to what we saw above for a simple `SELECT ... WHERE t2.unique2 = constant` case. (The estimated cost is actually a bit lower than what was seen above, as a result of caching that's expected to occur during the repeated index scans on `t2`.) The costs of the loop node are then set on the basis of the cost of the outer scan, plus one repetition of the inner scan for each outer row (10 * 7.87, here), plus a little CPU time for join processing.

In this example the join's output row count is the same as the product of the two scans' row counts, but that's not true in all cases because there can be additional `WHERE` clauses that mention both tables and so can only be applied at the join point, not to either input scan. Here's an example:

```
EXPLAIN SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t2.unique2 < 10 AND t1.hundred < t2.hundred;

                                      QUERY PLAN
--------------------------------------------------------------------------------------
 Nested Loop  (cost=4.65..49.46 rows=33 width=488)
   Join Filter: (t1.hundred < t2.hundred)
   ->  Bitmap Heap Scan on tenk1 t1  (cost=4.36..39.47 rows=10 width=244)
         Recheck Cond: (unique1 < 10)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..4.36 rows=10 width=0)
               Index Cond: (unique1 < 10)
   ->  Materialize  (cost=0.29..8.51 rows=10 width=244)
         ->  Index Scan using tenk2_unique2 on tenk2 t2  (cost=0.29..8.46 rows=10 width=
               Index Cond: (unique2 < 10)
```

The condition `t1.hundred < t2.hundred` can't be tested in the `tenk2_unique2` index, so it's applied at the join node. This reduces the estimated output row count of the join node, but does not change either input scan.

Notice that here the planner has chosen to "materialize" the inner relation of the join, by putting a Materialize plan node atop it. This means that the `t2` index scan will be done just once, even though the nested-loop join node needs to read that data ten times, once for each row from the outer relation. The Materialize node saves the data in memory as it's read, and then returns the data from memory on each subsequent pass.

When dealing with outer joins, you might see join plan nodes with both "Join Filter" and plain "Filter" conditions attached. Join Filter conditions come from the outer join's `ON` clause, so a row that fails the Join Filter condition could still get emitted as a null-extended row. But a plain Filter condition is applied after the outer-join rules and so acts to remove rows unconditionally. In an inner join there is no semantic difference between these types of filters.

If we change the query's selectivity a bit, we might get a very different join plan:

```
EXPLAIN SELECT *
```

```
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                        QUERY PLAN
------------------------------------------------------------------------------------------
 Hash Join  (cost=230.47..713.98 rows=101 width=488)
   Hash Cond: (t2.unique2 = t1.unique2)
   ->  Seq Scan on tenk2 t2  (cost=0.00..445.00 rows=10000 width=244)
   ->  Hash  (cost=229.20..229.20 rows=101 width=244)
         ->  Bitmap Heap Scan on tenk1 t1  (cost=5.07..229.20 rows=101 width=244)
               Recheck Cond: (unique1 < 100)
               ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0
                     Index Cond: (unique1 < 100)
```

Here, the planner has chosen to use a hash join, in which rows of one table are entered into an in-memory hash table, after which the other table is scanned and the hash table is probed for matches to each row. Again note how the indentation reflects the plan structure: the bitmap scan on `tenk1` is the input to the Hash node, which constructs the hash table. That's then returned to the Hash Join node, which reads rows from its outer child plan and searches the hash table for each one.

Another possible type of join is a merge join, illustrated here:

```
EXPLAIN SELECT *
FROM tenk1 t1, onek t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                        QUERY PLAN
------------------------------------------------------------------------------------------
 Merge Join  (cost=198.11..268.19 rows=10 width=488)
   Merge Cond: (t1.unique2 = t2.unique2)
   ->  Index Scan using tenk1_unique2 on tenk1 t1  (cost=0.29..656.28 rows=101 width=244
         Filter: (unique1 < 100)
   ->  Sort  (cost=197.83..200.33 rows=1000 width=244)
         Sort Key: t2.unique2
         ->  Seq Scan on onek t2  (cost=0.00..148.00 rows=1000 width=244)
```

Merge join requires its input data to be sorted on the join keys. In this plan the `tenk1` data is sorted by using an index scan to visit the rows in the correct order, but a sequential scan and sort is preferred for `onek`, because there are many more rows to be visited in that table. (Sequential-scan-and-sort frequently beats an index scan for sorting many rows, because of the nonsequential disk access required by the index scan.)

One way to look at variant plans is to force the planner to disregard whatever strategy it thought was the cheapest, using the enable/disable flags described in Section 18.7.1. (This is a crude tool, but useful. See also Section 14.3.) For example, if we're unconvinced that sequential-scan-and-sort is the best way to deal with table `onek` in the previous example, we could try

```
SET enable_sort = off;

EXPLAIN SELECT *
FROM tenk1 t1, onek t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                        QUERY PLAN
```

```
-----------------------------------------------------------------------------------------
 Merge Join  (cost=0.56..292.65 rows=10 width=488)
   Merge Cond: (t1.unique2 = t2.unique2)
   ->  Index Scan using tenk1_unique2 on tenk1 t1  (cost=0.29..656.28 rows=101 width=244
         Filter: (unique1 < 100)
   ->  Index Scan using onek_unique2 on onek t2  (cost=0.28..224.79 rows=1000 width=244)
```

which shows that the planner thinks that sorting `onek` by index-scanning is about 12% more expensive than sequential-scan-and-sort. Of course, the next question is whether it's right about that. We can investigate that using `EXPLAIN ANALYZE`, as discussed below.

14.1.2. EXPLAIN ANALYZE

It is possible to check the accuracy of the planner's estimates by using `EXPLAIN`'s `ANALYZE` option. With this option, `EXPLAIN` actually executes the query, and then displays the true row counts and true run time accumulated within each plan node, along with the same estimates that a plain `EXPLAIN` shows. For example, we might get a result like this:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 10 AND t1.unique2 = t2.unique2;

                                                          QUERY PLAN
-----------------------------------------------------------------------------------------
 Nested Loop  (cost=4.65..118.62 rows=10 width=488) (actual time=0.128..0.377 rows=10 lo
   ->  Bitmap Heap Scan on tenk1 t1  (cost=4.36..39.47 rows=10 width=244) (actual time=0
         Recheck Cond: (unique1 < 10)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..4.36 rows=10 width=0) (actu
               Index Cond: (unique1 < 10)
   ->  Index Scan using tenk2_unique2 on tenk2 t2  (cost=0.29..7.91 rows=1 width=244) (a
         Index Cond: (unique2 = t1.unique2)
 Planning time: 0.181 ms
 Execution time: 0.501 ms
```

Note that the "actual time" values are in milliseconds of real time, whereas the `cost` estimates are expressed in arbitrary units; so they are unlikely to match up. The thing that's usually most important to look for is whether the estimated row counts are reasonably close to reality. In this example the estimates were all dead-on, but that's quite unusual in practice.

In some query plans, it is possible for a subplan node to be executed more than once. For example, the inner index scan will be executed once per outer row in the above nested-loop plan. In such cases, the `loops` value reports the total number of executions of the node, and the actual time and rows values shown are averages per-execution. This is done to make the numbers comparable with the way that the cost estimates are shown. Multiply by the `loops` value to get the total time actually spent in the node. In the above example, we spent a total of 0.220 milliseconds executing the index scans on `tenk2`.

In some cases `EXPLAIN ANALYZE` shows additional execution statistics beyond the plan node execution times and row counts. For example, Sort and Hash nodes provide extra information:

```
EXPLAIN ANALYZE SELECT *
FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2 ORDER BY t1.fivethous;

                                                                QUERY PLAN
```

```
------------------------------------------------------------------------------------------
 Sort  (cost=717.34..717.59 rows=101 width=488) (actual time=7.761..7.774 rows=100 loops
   Sort Key: t1.fivethous
   Sort Method: quicksort  Memory: 77kB
   ->  Hash Join  (cost=230.47..713.98 rows=101 width=488) (actual time=0.711..7.427 row
         Hash Cond: (t2.unique2 = t1.unique2)
         ->  Seq Scan on tenk2 t2  (cost=0.00..445.00 rows=10000 width=244) (actual time
         ->  Hash  (cost=229.20..229.20 rows=101 width=244) (actual time=0.659..0.659 ro
               Buckets: 1024  Batches: 1  Memory Usage: 28kB
               ->  Bitmap Heap Scan on tenk1 t1  (cost=5.07..229.20 rows=101 width=244)
                     Recheck Cond: (unique1 < 100)
                     ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 w
                           Index Cond: (unique1 < 100)
 Planning time: 0.194 ms
 Execution time: 8.008 ms
```

The Sort node shows the sort method used (in particular, whether the sort was in-memory or on-disk) and the amount of memory or disk space needed. The Hash node shows the number of hash buckets and batches as well as the peak amount of memory used for the hash table. (If the number of batches exceeds one, there will also be disk space usage involved, but that is not shown.)

Another type of extra information is the number of rows removed by a filter condition:

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE ten < 7;

                                                 QUERY PLAN
------------------------------------------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..483.00 rows=7000 width=244) (actual time=0.016..5.107 ro
   Filter: (ten < 7)
   Rows Removed by Filter: 3000
 Planning time: 0.083 ms
 Execution time: 5.905 ms
```

These counts can be particularly valuable for filter conditions applied at join nodes. The “Rows Removed” line only appears when at least one scanned row, or potential join pair in the case of a join node, is rejected by the filter condition.

A case similar to filter conditions occurs with “lossy” index scans. For example, consider this search for polygons containing a specific point:

```
EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon '(0.5,2.0)';

                                               QUERY PLAN
------------------------------------------------------------------------------------------
 Seq Scan on polygon_tbl  (cost=0.00..1.05 rows=1 width=32) (actual time=0.044..0.044 ro
   Filter: (f1 @> '((0.5,2))'::polygon)
   Rows Removed by Filter: 4
 Planning time: 0.040 ms
 Execution time: 0.083 ms
```

The planner thinks (quite correctly) that this sample table is too small to bother with an index scan, so we have a plain sequential scan in which all the rows got rejected by the filter condition. But if we force an index scan to be used, we see:

```
SET enable_seqscan TO off;

EXPLAIN ANALYZE SELECT * FROM polygon_tbl WHERE f1 @> polygon '(0.5,2.0)';
```

```
                                                        QUERY PLAN
-----------------------------------------------------------------------------------------
 Index Scan using gpolygonind on polygon_tbl  (cost=0.13..8.15 rows=1 width=32) (actual
   Index Cond: (f1 @> '((0.5,2))'::polygon)
   Rows Removed by Index Recheck: 1
 Planning time: 0.034 ms
 Execution time: 0.144 ms
```

Here we can see that the index returned one candidate row, which was then rejected by a recheck of the index condition. This happens because a GiST index is "lossy" for polygon containment tests: it actually returns the rows with polygons that overlap the target, and then we have to do the exact containment test on those rows.

`EXPLAIN` has a `BUFFERS` option that can be used with `ANALYZE` to get even more run time statistics:

```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000;

                                                          QUERY PLAN
-----------------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=25.08..60.21 rows=10 width=244) (actual time=0.323..0.
   Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
   Buffers: shared hit=15
   ->  BitmapAnd  (cost=25.08..25.08 rows=10 width=0) (actual time=0.309..0.309 rows=0 l
         Buffers: shared hit=7
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0) (act
               Index Cond: (unique1 < 100)
               Buffers: shared hit=2
         ->  Bitmap Index Scan on tenk1_unique2  (cost=0.00..19.78 rows=999 width=0) (ac
               Index Cond: (unique2 > 9000)
               Buffers: shared hit=5
 Planning time: 0.088 ms
 Execution time: 0.423 ms
```

The numbers provided by `BUFFERS` help to identify which parts of the query are the most I/O-intensive.

Keep in mind that because `EXPLAIN ANALYZE` actually runs the query, any side-effects will happen as usual, even though whatever results the query might output are discarded in favor of printing the `EXPLAIN` data. If you want to analyze a data-modifying query without changing your tables, you can roll the command back afterwards, for example:

```
BEGIN;

EXPLAIN ANALYZE UPDATE tenk1 SET hundred = hundred + 1 WHERE unique1 < 100;

                                                          QUERY PLAN
-----------------------------------------------------------------------------------------
 Update on tenk1  (cost=5.07..229.46 rows=101 width=250) (actual time=14.628..14.628 row
   ->  Bitmap Heap Scan on tenk1  (cost=5.07..229.46 rows=101 width=250) (actual time=0.
         Recheck Cond: (unique1 < 100)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0) (act
               Index Cond: (unique1 < 100)
 Planning time: 0.079 ms
 Execution time: 14.727 ms

ROLLBACK;
```

As seen in this example, when the query is an INSERT, UPDATE, or DELETE command, the actual work of applying the table changes is done by a top-level Insert, Update, or Delete plan node. The plan nodes underneath this node perform the work of locating the old rows and/or computing the new data. So above, we see the same sort of bitmap table scan we've seen already, and its output is fed to an Update node that stores the updated rows. It's worth noting that although the data-modifying node can take a considerable amount of run time (here, it's consuming the lion's share of the time), the planner does not currently add anything to the cost estimates to account for that work. That's because the work to be done is the same for every correct query plan, so it doesn't affect planning decisions.

The Planning time shown by EXPLAIN ANALYZE is the time it took to generate the query plan from the parsed query and optimize it. It does not include parsing or rewriting.

The Execution time shown by EXPLAIN ANALYZE includes executor start-up and shut-down time, as well as the time to run any triggers that are fired, but it does not include parsing, rewriting, or planning time. Time spent executing BEFORE triggers, if any, is included in the time for the related Insert, Update, or Delete node; but time spent executing AFTER triggers is not counted there because AFTER triggers are fired after completion of the whole plan. The total time spent in each trigger (either BEFORE or AFTER) is also shown separately. Note that deferred constraint triggers will not be executed until end of transaction and are thus not considered at all by EXPLAIN ANALYZE.

14.1.3. Caveats

There are two significant ways in which run times measured by EXPLAIN ANALYZE can deviate from normal execution of the same query. First, since no output rows are delivered to the client, network transmission costs and I/O conversion costs are not included. Second, the measurement overhead added by EXPLAIN ANALYZE can be significant, especially on machines with slow gettimeofday() operating-system calls. You can use the pg_test_timing tool to measure the overhead of timing on your system.

EXPLAIN results should not be extrapolated to situations much different from the one you are actually testing; for example, results on a toy-sized table cannot be assumed to apply to large tables. The planner's cost estimates are not linear and so it might choose a different plan for a larger or smaller table. An extreme example is that on a table that only occupies one disk page, you'll nearly always get a sequential scan plan whether indexes are available or not. The planner realizes that it's going to take one disk page read to process the table in any case, so there's no value in expending additional page reads to look at an index. (We saw this happening in the polygon_tbl example above.)

There are cases in which the actual and estimated values won't match up well, but nothing is really wrong. One such case occurs when plan node execution is stopped short by a LIMIT or similar effect. For example, in the LIMIT query we used before,

```
EXPLAIN ANALYZE SELECT * FROM tenk1 WHERE unique1 < 100 AND unique2 > 9000 LIMIT 2;

                                                                  QUERY PLAN
-----------------------------------------------------------------------------------------------
 Limit  (cost=0.29..14.71 rows=2 width=244) (actual time=0.177..0.249 rows=2 loops=1)
   ->  Index Scan using tenk1_unique2 on tenk1  (cost=0.29..72.42 rows=10 width=244) (ac
         Index Cond: (unique2 > 9000)
         Filter: (unique1 < 100)
         Rows Removed by Filter: 287
 Planning time: 0.096 ms
 Execution time: 0.336 ms
```

the estimated cost and row count for the Index Scan node are shown as though it were run to completion. But in reality the Limit node stopped requesting rows after it got two, so the actual row count is

only 2 and the run time is less than the cost estimate would suggest. This is not an estimation error, only a discrepancy in the way the estimates and true values are displayed.

Merge joins also have measurement artifacts that can confuse the unwary. A merge join will stop reading one input if it's exhausted the other input and the next key value in the one input is greater than the last key value of the other input; in such a case there can be no more matches and so no need to scan the rest of the first input. This results in not reading all of one child, with results like those mentioned for `LIMIT`. Also, if the outer (first) child contains rows with duplicate key values, the inner (second) child is backed up and rescanned for the portion of its rows matching that key value. `EXPLAIN ANALYZE` counts these repeated emissions of the same inner rows as if they were real additional rows. When there are many outer duplicates, the reported actual row count for the inner child plan node can be significantly larger than the number of rows that are actually in the inner relation.

BitmapAnd and BitmapOr nodes always report their actual row counts as zero, due to implementation limitations.

14.2. Statistics Used by the Planner

As we saw in the previous section, the query planner needs to estimate the number of rows retrieved by a query in order to make good choices of query plans. This section provides a quick look at the statistics that the system uses for these estimates.

One component of the statistics is the total number of entries in each table and index, as well as the number of disk blocks occupied by each table and index. This information is kept in the table `pg_class`, in the columns `reltuples` and `relpages`. We can look at it with queries similar to this one:

```
SELECT relname, relkind, reltuples, relpages
FROM pg_class
WHERE relname LIKE 'tenk1%';

       relname        | relkind | reltuples | relpages
----------------------+---------+-----------+----------
 tenk1                | r       |     10000 |      358
 tenk1_hundred        | i       |     10000 |       30
 tenk1_thous_tenthous | i       |     10000 |       30
 tenk1_unique1        | i       |     10000 |       30
 tenk1_unique2        | i       |     10000 |       30
(5 rows)
```

Here we can see that `tenk1` contains 10000 rows, as do its indexes, but the indexes are (unsurprisingly) much smaller than the table.

For efficiency reasons, `reltuples` and `relpages` are not updated on-the-fly, and so they usually contain somewhat out-of-date values. They are updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`. A `VACUUM` or `ANALYZE` operation that does not scan the entire table (which is commonly the case) will incrementally update the `reltuples` count on the basis of the part of the table it did scan, resulting in an approximate value. In any case, the planner will scale the values it finds in `pg_class` to match the current physical table size, thus obtaining a closer approximation.

Most queries retrieve only a fraction of the rows in a table, due to `WHERE` clauses that restrict the rows to be examined. The planner thus needs to make an estimate of the *selectivity* of `WHERE` clauses, that is, the fraction of rows that match each condition in the `WHERE` clause. The information used for this

task is stored in the pg_statistic system catalog. Entries in pg_statistic are updated by the ANALYZE and VACUUM ANALYZE commands, and are always approximate even when freshly updated.

Rather than look at pg_statistic directly, it's better to look at its view pg_stats when examining the statistics manually. pg_stats is designed to be more easily readable. Furthermore, pg_stats is readable by all, whereas pg_statistic is only readable by a superuser. (This prevents unprivileged users from learning something about the contents of other people's tables from the statistics. The pg_stats view is restricted to show only rows about tables that the current user can read.) For example, we might do:

```
SELECT attname, inherited, n_distinct,
       array_to_string(most_common_vals, E'\n') as most_common_vals
FROM pg_stats
WHERE tablename = 'road';

 attname | inherited | n_distinct |          most_common_vals
---------+-----------+------------+------------------------------------
 name    | f         |  -0.363388 | I- 580                          Ramp+
         |           |            | I- 880                          Ramp+
         |           |            | Sp Railroad                         +
         |           |            | I- 580                              +
         |           |            | I- 680                          Ramp
 name    | t         |  -0.284859 | I- 880                          Ramp+
         |           |            | I- 580                          Ramp+
         |           |            | I- 680                          Ramp+
         |           |            | I- 580                              +
         |           |            | State Hwy 13                    Ramp
(2 rows)
```

Note that two rows are displayed for the same column, one corresponding to the complete inheritance hierarchy starting at the road table (inherited=t), and another one including only the road table itself (inherited=f).

The amount of information stored in pg_statistic by ANALYZE, in particular the maximum number of entries in the most_common_vals and histogram_bounds arrays for each column, can be set on a column-by-column basis using the ALTER TABLE SET STATISTICS command, or globally by setting the default_statistics_target configuration variable. The default limit is presently 100 entries. Raising the limit might allow more accurate planner estimates to be made, particularly for columns with irregular data distributions, at the price of consuming more space in pg_statistic and slightly more time to compute the estimates. Conversely, a lower limit might be sufficient for columns with simple data distributions.

Further details about the planner's use of statistics can be found in Chapter 61.

14.3. Controlling the Planner with Explicit JOIN Clauses

It is possible to control the query planner to some extent by using the explicit JOIN syntax. To see why this matters, we first need some background.

In a simple join query, such as:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
```

the planner is free to join the given tables in any order. For example, it could generate a query plan that joins A to B, using the WHERE condition a.id = b.id, and then joins C to this joined table,

using the other WHERE condition. Or it could join B to C and then join A to that result. Or it could join A to C and then join them with B — but that would be inefficient, since the full Cartesian product of A and C would have to be formed, there being no applicable condition in the WHERE clause to allow optimization of the join. (All joins in the PostgreSQL executor happen between two input tables, so it's necessary to build up the result in one or another of these fashions.) The important point is that these different join possibilities give semantically equivalent results but might have hugely different execution costs. Therefore, the planner will explore all of them to try to find the most efficient query plan.

When a query only involves two or three tables, there aren't many join orders to worry about. But the number of possible join orders grows exponentially as the number of tables expands. Beyond ten or so input tables it's no longer practical to do an exhaustive search of all the possibilities, and even for six or seven tables planning might take an annoyingly long time. When there are too many input tables, the PostgreSQL planner will switch from exhaustive search to a *genetic* probabilistic search through a limited number of possibilities. (The switch-over threshold is set by the geqo_threshold run-time parameter.) The genetic search takes less time, but it won't necessarily find the best possible plan.

When the query involves outer joins, the planner has less freedom than it does for plain (inner) joins. For example, consider:

```
SELECT * FROM a LEFT JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

Although this query's restrictions are superficially similar to the previous example, the semantics are different because a row must be emitted for each row of A that has no matching row in the join of B and C. Therefore the planner has no choice of join order here: it must join B to C and then join A to that result. Accordingly, this query takes less time to plan than the previous query. In other cases, the planner might be able to determine that more than one join order is safe. For example, given:

```
SELECT * FROM a LEFT JOIN b ON (a.bid = b.id) LEFT JOIN c ON (a.cid = c.id);
```

it is valid to join A to either B or C first. Currently, only FULL JOIN completely constrains the join order. Most practical cases involving LEFT JOIN or RIGHT JOIN can be rearranged to some extent.

Explicit inner join syntax (INNER JOIN, CROSS JOIN, or unadorned JOIN) is semantically the same as listing the input relations in FROM, so it does not constrain the join order.

Even though most kinds of JOIN don't completely constrain the join order, it is possible to instruct the PostgreSQL query planner to treat all JOIN clauses as constraining the join order anyway. For example, these three queries are logically equivalent:

```
SELECT * FROM a, b, c WHERE a.id = b.id AND b.ref = c.id;
SELECT * FROM a CROSS JOIN b CROSS JOIN c WHERE a.id = b.id AND b.ref = c.id;
SELECT * FROM a JOIN (b JOIN c ON (b.ref = c.id)) ON (a.id = b.id);
```

But if we tell the planner to honor the JOIN order, the second and third take less time to plan than the first. This effect is not worth worrying about for only three tables, but it can be a lifesaver with many tables.

To force the planner to follow the join order laid out by explicit JOINs, set the join_collapse_limit run-time parameter to 1. (Other possible values are discussed below.)

You do not need to constrain the join order completely in order to cut search time, because it's OK to use JOIN operators within items of a plain FROM list. For example, consider:

```
SELECT * FROM a CROSS JOIN b, c, d, e WHERE ...;
```

With join_collapse_limit = 1, this forces the planner to join A to B before joining them to other tables, but doesn't constrain its choices otherwise. In this example, the number of possible join orders is reduced by a factor of 5.

Constraining the planner's search in this way is a useful technique both for reducing planning time and for directing the planner to a good query plan. If the planner chooses a bad join order by default, you can force it to choose a better order via JOIN syntax — assuming that you know of a better order, that is. Experimentation is recommended.

A closely related issue that affects planning time is collapsing of subqueries into their parent query. For example, consider:

```
SELECT *
FROM x, y,
    (SELECT * FROM a, b, c WHERE something) AS ss
WHERE somethingelse;
```

This situation might arise from use of a view that contains a join; the view's SELECT rule will be inserted in place of the view reference, yielding a query much like the above. Normally, the planner will try to collapse the subquery into the parent, yielding:

```
SELECT * FROM x, y, a, b, c WHERE something AND somethingelse;
```

This usually results in a better plan than planning the subquery separately. (For example, the outer WHERE conditions might be such that joining X to A first eliminates many rows of A, thus avoiding the need to form the full logical output of the subquery.) But at the same time, we have increased the planning time; here, we have a five-way join problem replacing two separate three-way join problems. Because of the exponential growth of the number of possibilities, this makes a big difference. The planner tries to avoid getting stuck in huge join search problems by not collapsing a subquery if more than from_collapse_limit FROM items would result in the parent query. You can trade off planning time against quality of plan by adjusting this run-time parameter up or down.

from_collapse_limit and join_collapse_limit are similarly named because they do almost the same thing: one controls when the planner will "flatten out" subqueries, and the other controls when it will flatten out explicit joins. Typically you would either set join_collapse_limit equal to from_collapse_limit (so that explicit joins and subqueries act similarly) or set join_collapse_limit to 1 (if you want to control join order with explicit joins). But you might set them differently if you are trying to fine-tune the trade-off between planning time and run time.

14.4. Populating a Database

One might need to insert a large amount of data when first populating a database. This section contains some suggestions on how to make this process as efficient as possible.

14.4.1. Disable Autocommit

When using multiple INSERTs, turn off autocommit and just do one commit at the end. (In plain SQL, this means issuing BEGIN at the start and COMMIT at the end. Some client libraries might do this behind your back, in which case you need to make sure the library does it when you want it done.) If you allow each insertion to be committed separately, PostgreSQL is doing a lot of work for each row that is added. An additional benefit of doing all insertions in one transaction is that if the insertion of one row were to fail then the insertion of all rows inserted up to that point would be rolled back, so you won't be stuck with partially loaded data.

14.4.2. Use COPY

Use COPY to load all the rows in one command, instead of using a series of INSERT commands. The COPY command is optimized for loading large numbers of rows; it is less flexible than INSERT, but incurs significantly less overhead for large data loads. Since COPY is a single command, there is no need to disable autocommit if you use this method to populate a table.

If you cannot use COPY, it might help to use PREPARE to create a prepared INSERT statement, and then use EXECUTE as many times as required. This avoids some of the overhead of repeatedly parsing and planning INSERT. Different interfaces provide this facility in different ways; look for "prepared statements" in the interface documentation.

Note that loading a large number of rows using COPY is almost always faster than using INSERT, even if PREPARE is used and multiple insertions are batched into a single transaction.

COPY is fastest when used within the same transaction as an earlier CREATE TABLE or TRUNCATE command. In such cases no WAL needs to be written, because in case of an error, the files containing the newly loaded data will be removed anyway. However, this consideration only applies when wal_level is minimal as all commands must write WAL otherwise.

14.4.3. Remove Indexes

If you are loading a freshly created table, the fastest method is to create the table, bulk load the table's data using COPY, then create any indexes needed for the table. Creating an index on pre-existing data is quicker than updating it incrementally as each row is loaded.

If you are adding large amounts of data to an existing table, it might be a win to drop the indexes, load the table, and then recreate the indexes. Of course, the database performance for other users might suffer during the time the indexes are missing. One should also think twice before dropping a unique index, since the error checking afforded by the unique constraint will be lost while the index is missing.

14.4.4. Remove Foreign Key Constraints

Just as with indexes, a foreign key constraint can be checked "in bulk" more efficiently than row-by-row. So it might be useful to drop foreign key constraints, load data, and re-create the constraints. Again, there is a trade-off between data load speed and loss of error checking while the constraint is missing.

What's more, when you load data into a table with existing foreign key constraints, each new row requires an entry in the server's list of pending trigger events (since it is the firing of a trigger that checks the row's foreign key constraint). Loading many millions of rows can cause the trigger event queue to overflow available memory, leading to intolerable swapping or even outright failure of the command. Therefore it may be *necessary*, not just desirable, to drop and re-apply foreign keys when loading large amounts of data. If temporarily removing the constraint isn't acceptable, the only other recourse may be to split up the load operation into smaller transactions.

14.4.5. Increase maintenance_work_mem

Temporarily increasing the maintenance_work_mem configuration variable when loading large amounts of data can lead to improved performance. This will help to speed up CREATE INDEX

commands and ALTER TABLE ADD FOREIGN KEY commands. It won't do much for COPY itself, so this advice is only useful when you are using one or both of the above techniques.

14.4.6. Increase checkpoint_segments

Temporarily increasing the checkpoint_segments configuration variable can also make large data loads faster. This is because loading a large amount of data into PostgreSQL will cause checkpoints to occur more often than the normal checkpoint frequency (specified by the checkpoint_timeout configuration variable). Whenever a checkpoint occurs, all dirty pages must be flushed to disk. By increasing checkpoint_segments temporarily during bulk data loads, the number of checkpoints that are required can be reduced.

14.4.7. Disable WAL Archival and Streaming Replication

When loading large amounts of data into an installation that uses WAL archiving or streaming replication, it might be faster to take a new base backup after the load has completed than to process a large amount of incremental WAL data. To prevent incremental WAL logging while loading, disable archiving and streaming replication, by setting wal_level to minimal, archive_mode to off, and max_wal_senders to zero. But note that changing these settings requires a server restart.

Aside from avoiding the time for the archiver or WAL sender to process the WAL data, doing this will actually make certain commands faster, because they are designed not to write WAL at all if wal_level is minimal. (They can guarantee crash safety more cheaply by doing an fsync at the end than by writing WAL.) This applies to the following commands:

- CREATE TABLE AS SELECT
- CREATE INDEX (and variants such as ALTER TABLE ADD PRIMARY KEY)
- ALTER TABLE SET TABLESPACE
- CLUSTER
- COPY FROM, when the target table has been created or truncated earlier in the same transaction

14.4.8. Run ANALYZE Afterwards

Whenever you have significantly altered the distribution of data within a table, running ANALYZE is strongly recommended. This includes bulk loading large amounts of data into the table. Running ANALYZE (or VACUUM ANALYZE) ensures that the planner has up-to-date statistics about the table. With no statistics or obsolete statistics, the planner might make poor decisions during query planning, leading to poor performance on any tables with inaccurate or nonexistent statistics. Note that if the autovacuum daemon is enabled, it might run ANALYZE automatically; see Section 23.1.3 and Section 23.1.6 for more information.

14.4.9. Some Notes About pg_dump

Dump scripts generated by pg_dump automatically apply several, but not all, of the above guidelines. To reload a pg_dump dump as quickly as possible, you need to do a few extra things manually. (Note

that these points apply while *restoring* a dump, not while *creating* it. The same points apply whether loading a text dump with psql or using pg_restore to load from a pg_dump archive file.)

By default, pg_dump uses `COPY`, and when it is generating a complete schema-and-data dump, it is careful to load data before creating indexes and foreign keys. So in this case several guidelines are handled automatically. What is left for you to do is to:

- Set appropriate (i.e., larger than normal) values for `maintenance_work_mem` and `checkpoint_segments`.
- If using WAL archiving or streaming replication, consider disabling them during the restore. To do that, set `archive_mode` to `off`, `wal_level` to `minimal`, and `max_wal_senders` to zero before loading the dump. Afterwards, set them back to the right values and take a fresh base backup.
- Experiment with the parallel dump and restore modes of both pg_dump and pg_restore and find the optimal number of concurrent jobs to use. Dumping and restoring in parallel by means of the `-j` option should give you a significantly higher performance over the serial mode.
- Consider whether the whole dump should be restored as a single transaction. To do that, pass the `-1` or `--single-transaction` command-line option to psql or pg_restore. When using this mode, even the smallest of errors will rollback the entire restore, possibly discarding many hours of processing. Depending on how interrelated the data is, that might seem preferable to manual cleanup, or not. `COPY` commands will run fastest if you use a single transaction and have WAL archiving turned off.
- If multiple CPUs are available in the database server, consider using pg_restore's `--jobs` option. This allows concurrent data loading and index creation.
- Run `ANALYZE` afterwards.

A data-only dump will still use `COPY`, but it does not drop or recreate indexes, and it does not normally touch foreign keys. [1] So when loading a data-only dump, it is up to you to drop and recreate indexes and foreign keys if you wish to use those techniques. It's still useful to increase `checkpoint_segments` while loading the data, but don't bother increasing `maintenance_work_mem`; rather, you'd do that while manually recreating indexes and foreign keys afterwards. And don't forget to `ANALYZE` when you're done; see Section 23.1.3 and Section 23.1.6 for more information.

14.5. Non-Durable Settings

Durability is a database feature that guarantees the recording of committed transactions even if the server crashes or loses power. However, durability adds significant database overhead, so if your site does not require such a guarantee, PostgreSQL can be configured to run much faster. The following are configuration changes you can make to improve performance in such cases. Except as noted below, durability is still guaranteed in case of a crash of the database software; only abrupt operating system stoppage creates a risk of data loss or corruption when these settings are used.

- Place the database cluster's data directory in a memory-backed file system (i.e. RAM disk). This eliminates all database disk I/O, but limits data storage to the amount of available memory (and

1. You can get the effect of disabling foreign keys by using the `--disable-triggers` option — but realize that that eliminates, rather than just postpones, foreign key validation, and so it is possible to insert bad data if you use it.

perhaps swap).

- Turn off fsync; there is no need to flush data to disk.
- Turn off synchronous_commit; there might be no need to force WAL writes to disk on every commit. This setting does risk transaction loss (though not data corruption) in case of a crash of the *database*.
- Turn off full_page_writes; there is no need to guard against partial page writes.
- Increase checkpoint_segments and checkpoint_timeout ; this reduces the frequency of checkpoints, but increases the storage requirements of `/pg_xlog`.
- Create unlogged tables to avoid WAL writes, though it makes the tables non-crash-safe.

III. Server Administration

This part covers topics that are of interest to a PostgreSQL database administrator. This includes installation of the software, set up and configuration of the server, management of users and databases, and maintenance tasks. Anyone who runs a PostgreSQL server, even for personal use, but especially in production, should be familiar with the topics covered in this part.

The information in this part is arranged approximately in the order in which a new user should read it. But the chapters are self-contained and can be read individually as desired. The information in this part is presented in a narrative fashion in topical units. Readers looking for a complete description of a particular command should see Part VI.

The first few chapters are written so they can be understood without prerequisite knowledge, so new users who need to set up their own server can begin their exploration with this part. The rest of this part is about tuning and management; that material assumes that the reader is familiar with the general use of the PostgreSQL database system. Readers are encouraged to look at Part I and Part II for additional information.

Chapter 15. Installation from Source Code

This chapter describes the installation of PostgreSQL using the source code distribution. (If you are installing a pre-packaged distribution, such as an RPM or Debian package, ignore this chapter and read the packager's instructions instead.)

15.1. Short Version

```
./configure
make
su
make install
adduser postgres
mkdir /usr/local/pgsql/data
chown postgres /usr/local/pgsql/data
su - postgres
/usr/local/pgsql/bin/initdb -D /usr/local/pgsql/data
/usr/local/pgsql/bin/postgres -D /usr/local/pgsql/data >logfile 2>&1 &
/usr/local/pgsql/bin/createdb test
/usr/local/pgsql/bin/psql test
```

The long version is the rest of this chapter.

15.2. Requirements

In general, a modern Unix-compatible platform should be able to run PostgreSQL. The platforms that had received specific testing at the time of release are listed in Section 15.6 below. In the `doc` subdirectory of the distribution there are several platform-specific FAQ documents you might wish to consult if you are having trouble.

The following software packages are required for building PostgreSQL:

- GNU make version 3.80 or newer is required; other make programs or older GNU make versions will *not* work. (GNU make is sometimes installed under the name `gmake`.) To test for GNU make enter:

  ```
  make --version
  ```

- You need an ISO/ANSI C compiler (at least C89-compliant). Recent versions of GCC are recommended, but PostgreSQL is known to build using a wide variety of compilers from different vendors.
- tar is required to unpack the source distribution, in addition to either gzip or bzip2.
- The GNU Readline library is used by default. It allows psql (the PostgreSQL command line SQL interpreter) to remember each command you type, and allows you to use arrow keys to recall and edit previous commands. This is very helpful and is strongly recommended. If you don't want to use it then you must specify the `--without-readline` option to `configure`. As an alternative, you can often use the BSD-licensed `libedit` library, originally developed on NetBSD. The `libedit` library is GNU Readline-compatible and is used if `libreadline` is not found, or

if `--with-libedit-preferred` is used as an option to `configure`. If you are using a package-based Linux distribution, be aware that you need both the `readline` and `readline-devel` packages, if those are separate in your distribution.

- The zlib compression library is used by default. If you don't want to use it then you must specify the `--without-zlib` option to `configure`. Using this option disables support for compressed archives in pg_dump and pg_restore.

The following packages are optional. They are not required in the default configuration, but they are needed when certain build options are enabled, as explained below:

- To build the server programming language PL/Perl you need a full Perl installation, including the `libperl` library and the header files. Since PL/Perl will be a shared library, the `libperl` library must be a shared library also on most platforms. This appears to be the default in recent Perl versions, but it was not in earlier versions, and in any case it is the choice of whomever installed Perl at your site. If you intend to make more than incidental use of PL/Perl, you should ensure that the Perl installation was built with the `usemultiplicity` option enabled (`perl -V` will show whether this is the case).

  If you don't have the shared library but you need one, a message like this will appear during the PostgreSQL build to point out this fact:

  ```
  *** Cannot build PL/Perl because libperl is not a shared library.
  *** You might have to rebuild your Perl installation.  Refer to
  *** the documentation for details.
  ```

  (If you don't follow the on-screen output you will merely notice that the PL/Perl library object, `plperl.so` or similar, will not be installed.) If you see this, you will have to rebuild and install Perl manually to be able to build PL/Perl. During the configuration process for Perl, request a shared library.

- To build the PL/Python server programming language, you need a Python installation with the header files and the distutils module. The minimum required version is Python 2.3. (To work with function arguments of type `numeric`, a 2.3.x installation must include the separately-available `cdecimal` module; note the PL/Python regression tests will not pass if that is missing.) Python 3 is supported if it's version 3.1 or later; but see Section 43.1 when using Python 3.

  Since PL/Python will be a shared library, the `libpython` library must be a shared library also on most platforms. This is not the case in a default Python installation. If after building and installing PostgreSQL you have a file called `plpython.so` (possibly a different extension), then everything went well. Otherwise you should have seen a notice like this flying by:

  ```
  *** Cannot build PL/Python because libpython is not a shared library.
  *** You might have to rebuild your Python installation.  Refer to
  *** the documentation for details.
  ```

  That means you have to rebuild (part of) your Python installation to create this shared library.

  If you have problems, run Python 2.3 or later's configure using the `--enable-shared` flag. On some operating systems you don't have to build a shared library, but you will have to convince the PostgreSQL build system of this. Consult the `Makefile` in the `src/pl/plpython` directory for details.

- To build the PL/Tcl procedural language, you of course need a Tcl installation. If you are using a pre-8.4 release of Tcl, ensure that it was built without multithreading support.

- To enable Native Language Support (NLS), that is, the ability to display a program's messages in a language other than English, you need an implementation of the Gettext API. Some operating systems have this built-in (e.g., Linux, NetBSD, Solaris), for other systems you can download an

add-on package from http://www.gnu.org/software/gettext/. If you are using the Gettext implementation in the GNU C library then you will additionally need the GNU Gettext package for some utility programs. For any of the other implementations you will not need it.

- You need Kerberos, OpenSSL, OpenLDAP, and/or PAM, if you want to support authentication or encryption using those services.
- To build the PostgreSQL documentation, there is a separate set of requirements; see Section J.2.

If you are building from a Git tree instead of using a released source package, or if you want to do server development, you also need the following packages:

- GNU Flex and Bison are needed to build from a Git checkout, or if you changed the actual scanner and parser definition files. If you need them, be sure to get Flex 2.5.31 or later and Bison 1.875 or later. Other lex and yacc programs cannot be used.
- Perl 5.8 or later is needed to build from a Git checkout, or if you changed the input files for any of the build steps that use Perl scripts. If building on Windows you will need Perl in any case. Perl is also required to run some test suites.

If you need to get a GNU package, you can find it at your local GNU mirror site (see http://www.gnu.org/order/ftp.html for a list) or at ftp://ftp.gnu.org/gnu/.

Also check that you have sufficient disk space. You will need about 100 MB for the source tree during compilation and about 20 MB for the installation directory. An empty database cluster takes about 35 MB; databases take about five times the amount of space that a flat text file with the same data would take. If you are going to run the regression tests you will temporarily need up to an extra 150 MB. Use the `df` command to check free disk space.

15.3. Getting The Source

The PostgreSQL 9.4.1 sources can be obtained from the download section of our website: http://www.postgresql.org/download/. You should get a file named `postgresql-9.4.1.tar.gz` or `postgresql-9.4.1.tar.bz2`. After you have obtained the file, unpack it:

```
gunzip postgresql-9.4.1.tar.gz
tar xf postgresql-9.4.1.tar
```

(Use `bunzip2` instead of `gunzip` if you have the `.bz2` file.) This will create a directory `postgresql-9.4.1` under the current directory with the PostgreSQL sources. Change into that directory for the rest of the installation procedure.

You can also get the source directly from the version control repository, see Appendix I.

15.4. Installation Procedure

1. Configuration

The first step of the installation procedure is to configure the source tree for your system and choose the options you would like. This is done by running the `configure` script. For a default installation simply enter:

```
./configure
```

This script will run a number of tests to determine values for various system dependent variables and detect any quirks of your operating system, and finally will create several files in the build tree to record what it found. You can also run `configure` in a directory outside the source tree, if you want to keep the build directory separate. This procedure is also called a *VPATH* build. Here's how:

```
mkdir build_dir
cd build_dir
/path/to/source/tree/configure [options go here]
make
```

The default configuration will build the server and utilities, as well as all client applications and interfaces that require only a C compiler. All files will be installed under `/usr/local/pgsql` by default.

You can customize the build and installation process by supplying one or more of the following command line options to `configure`:

`--prefix=`*`PREFIX`*

Install all files under the directory *`PREFIX`* instead of `/usr/local/pgsql`. The actual files will be installed into various subdirectories; no files will ever be installed directly into the *`PREFIX`* directory.

If you have special needs, you can also customize the individual subdirectories with the following options. However, if you leave these with their defaults, the installation will be relocatable, meaning you can move the directory after installation. (The `man` and `doc` locations are not affected by this.)

For relocatable installs, you might want to use `configure`'s `--disable-rpath` option. Also, you will need to tell the operating system how to find the shared libraries.

`--exec-prefix=`*`EXEC-PREFIX`*

You can install architecture-dependent files under a different prefix, *`EXEC-PREFIX`*, than what *`PREFIX`* was set to. This can be useful to share architecture-independent files between hosts. If you omit this, then *`EXEC-PREFIX`* is set equal to *`PREFIX`* and both architecture-dependent and independent files will be installed under the same tree, which is probably what you want.

`--bindir=`*`DIRECTORY`*

Specifies the directory for executable programs. The default is *`EXEC-PREFIX`*`/bin`, which normally means `/usr/local/pgsql/bin`.

`--sysconfdir=`*`DIRECTORY`*

Sets the directory for various configuration files, *`PREFIX`*`/etc` by default.

`--libdir=`*`DIRECTORY`*

Sets the location to install libraries and dynamically loadable modules. The default is *`EXEC-PREFIX`*`/lib`.

`--includedir=`*`DIRECTORY`*

Sets the directory for installing C and C++ header files. The default is *`PREFIX`*`/include`.

`--datarootdir=`*DIRECTORY*

Sets the root directory for various types of read-only data files. This only sets the default for some of the following options. The default is *PREFIX*`/share`.

`--datadir=`*DIRECTORY*

Sets the directory for read-only data files used by the installed programs. The default is *DATAROOTDIR*. Note that this has nothing to do with where your database files will be placed.

`--localedir=`*DIRECTORY*

Sets the directory for installing locale data, in particular message translation catalog files. The default is *DATAROOTDIR*`/locale`.

`--mandir=`*DIRECTORY*

The man pages that come with PostgreSQL will be installed under this directory, in their respective `man`*x* subdirectories. The default is *DATAROOTDIR*`/man`.

`--docdir=`*DIRECTORY*

Sets the root directory for installing documentation files, except "man" pages. This only sets the default for the following options. The default value for this option is *DATAROOTDIR*`/doc/postgresql`.

`--htmldir=`*DIRECTORY*

The HTML-formatted documentation for PostgreSQL will be installed under this directory. The default is *DATAROOTDIR*.

Note: Care has been taken to make it possible to install PostgreSQL into shared installation locations (such as `/usr/local/include`) without interfering with the namespace of the rest of the system. First, the string "`/postgresql`" is automatically appended to `datadir`, `sysconfdir`, and `docdir`, unless the fully expanded directory name already contains the string "`postgres`" or "`pgsql`". For example, if you choose `/usr/local` as prefix, the documentation will be installed in `/usr/local/doc/postgresql`, but if the prefix is `/opt/postgres`, then it will be in `/opt/postgres/doc`. The public C header files of the client interfaces are installed into `includedir` and are namespace-clean. The internal header files and the server header files are installed into private directories under `includedir`. See the documentation of each interface for information about how to access its header files. Finally, a private subdirectory will also be created, if appropriate, under `libdir` for dynamically loadable modules.

`--with-extra-version=`*STRING*

Append *STRING* to the PostgreSQL version number. You can use this, for example, to mark binaries built from unreleased Git snapshots or containing custom patches with an extra version string such as a `git describe` identifier or a distribution package release number.

`--with-includes=`*DIRECTORIES*

DIRECTORIES is a colon-separated list of directories that will be added to the list the compiler searches for header files. If you have optional packages (such as GNU Readline) installed in a non-standard location, you have to use this option and probably also the corresponding `--with-libraries` option.

Example: `--with-includes=/opt/gnu/include:/usr/sup/include`.

`--with-libraries=`*`DIRECTORIES`*

`DIRECTORIES` is a colon-separated list of directories to search for libraries. You will probably have to use this option (and the corresponding `--with-includes` option) if you have packages installed in non-standard locations.

Example: `--with-libraries=/opt/gnu/lib:/usr/sup/lib`.

`--enable-nls[=`*`LANGUAGES`*`]`

Enables Native Language Support (NLS), that is, the ability to display a program's messages in a language other than English. *`LANGUAGES`* is an optional space-separated list of codes of the languages that you want supported, for example `--enable-nls='de fr'`. (The intersection between your list and the set of actually provided translations will be computed automatically.) If you do not specify a list, then all available translations are installed.

To use this option, you will need an implementation of the Gettext API; see above.

`--with-pgport=`*`NUMBER`*

Set *`NUMBER`* as the default port number for server and clients. The default is 5432. The port can always be changed later on, but if you specify it here then both server and clients will have the same default compiled in, which can be very convenient. Usually the only good reason to select a non-default value is if you intend to run multiple PostgreSQL servers on the same machine.

`--with-perl`

Build the PL/Perl server-side language.

`--with-python`

Build the PL/Python server-side language.

`--with-tcl`

Build the PL/Tcl server-side language.

`--with-tclconfig=`*`DIRECTORY`*

Tcl installs the file `tclConfig.sh`, which contains configuration information needed to build modules interfacing to Tcl. This file is normally found automatically at a well-known location, but if you want to use a different version of Tcl you can specify the directory in which to look for it.

`--with-gssapi`

Build with support for GSSAPI authentication. On many systems, the GSSAPI (usually a part of the Kerberos installation) system is not installed in a location that is searched by default (e.g., `/usr/include`, `/usr/lib`), so you must use the options `--with-includes` and `--with-libraries` in addition to this option. `configure` will check for the required header files and libraries to make sure that your GSSAPI installation is sufficient before proceeding.

`--with-krb-srvnam=`*`NAME`*

The default name of the Kerberos service principal used by GSSAPI. `postgres` is the default. There's usually no reason to change this unless you have a Windows environment, in which case it must be set to upper case `POSTGRES`.

`--with-openssl`

Build with support for SSL (encrypted) connections. This requires the OpenSSL package to be installed. `configure` will check for the required header files and libraries to make sure

that your OpenSSL installation is sufficient before proceeding.

`--with-pam`

Build with PAM (Pluggable Authentication Modules) support.

`--with-ldap`

Build with LDAP support for authentication and connection parameter lookup (see Section 31.17 and Section 19.3.7 for more information). On Unix, this requires the OpenLDAP package to be installed. On Windows, the default WinLDAP library is used. `configure` will check for the required header files and libraries to make sure that your OpenLDAP installation is sufficient before proceeding.

`--without-readline`

Prevents use of the Readline library (and libedit as well). This option disables command-line editing and history in psql, so it is not recommended.

`--with-libedit-preferred`

Favors the use of the BSD-licensed libedit library rather than GPL-licensed Readline. This option is significant only if you have both libraries installed; the default in that case is to use Readline.

`--with-bonjour`

Build with Bonjour support. This requires Bonjour support in your operating system. Recommended on OS X.

`--with-uuid=`*`LIBRARY`*

Build the uuid-ossp module (which provides functions to generate UUIDs), using the specified UUID library. *`LIBRARY`* must be one of:

- `bsd` to use the UUID functions found in FreeBSD, NetBSD, and some other BSD-derived systems
- `e2fs` to use the UUID library created by the `e2fsprogs` project; this library is present in most Linux systems and in OS X, and can be obtained for other platforms as well
- `ossp` to use the OSSP UUID library[1]

`--with-ossp-uuid`

Obsolete equivalent of `--with-uuid=ossp`.

`--with-libxml`

Build with libxml (enables SQL/XML support). Libxml version 2.6.23 or later is required for this feature.

Libxml installs a program `xml2-config` that can be used to detect the required compiler and linker options. PostgreSQL will use it automatically if found. To specify a libxml installation at an unusual location, you can either set the environment variable `XML2_CONFIG` to point to the `xml2-config` program belonging to the installation, or use the options `--with-includes` and `--with-libraries`.

`--with-libxslt`

Use libxslt when building the xml2 module. xml2 relies on this library to perform XSL transformations of XML.

1. http://www.ossp.org/pkg/lib/uuid/

`--disable-integer-datetimes`

Disable support for 64-bit integer storage for timestamps and intervals, and store datetime values as floating-point numbers instead. Floating-point datetime storage was the default in PostgreSQL releases prior to 8.4, but it is now deprecated, because it does not support microsecond precision for the full range of `timestamp` values. However, integer-based datetime storage requires a 64-bit integer type. Therefore, this option can be used when no such type is available, or for compatibility with applications written for prior versions of PostgreSQL. See Section 8.5 for more information.

`--disable-float4-byval`

Disable passing float4 values "by value", causing them to be passed "by reference" instead. This option costs performance, but may be needed for compatibility with old user-defined functions that are written in C and use the "version 0" calling convention. A better long-term solution is to update any such functions to use the "version 1" calling convention.

`--disable-float8-byval`

Disable passing float8 values "by value", causing them to be passed "by reference" instead. This option costs performance, but may be needed for compatibility with old user-defined functions that are written in C and use the "version 0" calling convention. A better long-term solution is to update any such functions to use the "version 1" calling convention. Note that this option affects not only float8, but also int8 and some related types such as timestamp. On 32-bit platforms, `--disable-float8-byval` is the default and it is not allowed to select `--enable-float8-byval`.

`--with-segsize=`*`SEGSIZE`*

Set the *segment size*, in gigabytes. Large tables are divided into multiple operating-system files, each of size equal to the segment size. This avoids problems with file size limits that exist on many platforms. The default segment size, 1 gigabyte, is safe on all supported platforms. If your operating system has "largefile" support (which most do, nowadays), you can use a larger segment size. This can be helpful to reduce the number of file descriptors consumed when working with very large tables. But be careful not to select a value larger than is supported by your platform and the file systems you intend to use. Other tools you might wish to use, such as tar, could also set limits on the usable file size. It is recommended, though not absolutely required, that this value be a power of 2. Note that changing this value requires an initdb.

`--with-blocksize=`*`BLOCKSIZE`*

Set the *block size*, in kilobytes. This is the unit of storage and I/O within tables. The default, 8 kilobytes, is suitable for most situations; but other values may be useful in special cases. The value must be a power of 2 between 1 and 32 (kilobytes). Note that changing this value requires an initdb.

`--with-wal-segsize=`*`SEGSIZE`*

Set the *WAL segment size*, in megabytes. This is the size of each individual file in the WAL log. It may be useful to adjust this size to control the granularity of WAL log shipping. The default size is 16 megabytes. The value must be a power of 2 between 1 and 64 (megabytes). Note that changing this value requires an initdb.

`--with-wal-blocksize=`*`BLOCKSIZE`*

Set the *WAL block size*, in kilobytes. This is the unit of storage and I/O within the WAL log. The default, 8 kilobytes, is suitable for most situations; but other values may be useful in special cases. The value must be a power of 2 between 1 and 64 (kilobytes). Note that changing this value requires an initdb.

`--disable-spinlocks`

Allow the build to succeed even if PostgreSQL has no CPU spinlock support for the platform. The lack of spinlock support will result in poor performance; therefore, this option should only be used if the build aborts and informs you that the platform lacks spinlock support. If this option is required to build PostgreSQL on your platform, please report the problem to the PostgreSQL developers.

`--disable-thread-safety`

Disable the thread-safety of client libraries. This prevents concurrent threads in libpq and ECPG programs from safely controlling their private connection handles.

`--with-system-tzdata=`*`DIRECTORY`*

PostgreSQL includes its own time zone database, which it requires for date and time operations. This time zone database is in fact compatible with the IANA time zone database provided by many operating systems such as FreeBSD, Linux, and Solaris, so it would be redundant to install it again. When this option is used, the system-supplied time zone database in *`DIRECTORY`* is used instead of the one included in the PostgreSQL source distribution. *`DIRECTORY`* must be specified as an absolute path. `/usr/share/zoneinfo` is a likely directory on some operating systems. Note that the installation routine will not detect mismatching or erroneous time zone data. If you use this option, you are advised to run the regression tests to verify that the time zone data you have pointed to works correctly with PostgreSQL.

This option is mainly aimed at binary package distributors who know their target operating system well. The main advantage of using this option is that the PostgreSQL package won't need to be upgraded whenever any of the many local daylight-saving time rules change. Another advantage is that PostgreSQL can be cross-compiled more straightforwardly if the time zone database files do not need to be built during the installation.

`--without-zlib`

Prevents use of the Zlib library. This disables support for compressed archives in pg_dump and pg_restore. This option is only intended for those rare systems where this library is not available.

`--enable-debug`

Compiles all programs and libraries with debugging symbols. This means that you can run the programs in a debugger to analyze problems. This enlarges the size of the installed executables considerably, and on non-GCC compilers it usually also disables compiler optimization, causing slowdowns. However, having the symbols available is extremely helpful for dealing with any problems that might arise. Currently, this option is recommended for production installations only if you use GCC. But you should always have it on if you are doing development work or running a beta version.

`--enable-coverage`

If using GCC, all programs and libraries are compiled with code coverage testing instrumentation. When run, they generate files in the build directory with code coverage metrics. See Section 30.5 for more information. This option is for use only with GCC and when doing development work.

`--enable-profiling`

If using GCC, all programs and libraries are compiled so they can be profiled. On backend exit, a subdirectory will be created that contains the `gmon.out` file for use in profiling. This option is for use only with GCC and when doing development work.

`--enable-cassert`

Enables *assertion* checks in the server, which test for many "cannot happen" conditions. This is invaluable for code development purposes, but the tests can slow down the server significantly. Also, having the tests turned on won't necessarily enhance the stability of your server! The assertion checks are not categorized for severity, and so what might be a relatively harmless bug will still lead to server restarts if it triggers an assertion failure. This option is not recommended for production use, but you should have it on for development work or when running a beta version.

`--enable-depend`

Enables automatic dependency tracking. With this option, the makefiles are set up so that all affected object files will be rebuilt when any header file is changed. This is useful if you are doing development work, but is just wasted overhead if you intend only to compile once and install. At present, this option only works with GCC.

`--enable-dtrace`

Compiles PostgreSQL with support for the dynamic tracing tool DTrace. See Section 27.4 for more information.

To point to the `dtrace` program, the environment variable `DTRACE` can be set. This will often be necessary because `dtrace` is typically installed under `/usr/sbin`, which might not be in the path.

Extra command-line options for the `dtrace` program can be specified in the environment variable `DTRACEFLAGS`. On Solaris, to include DTrace support in a 64-bit binary, you must specify `DTRACEFLAGS="-64"` to configure. For example, using the GCC compiler:

```
./configure CC='gcc -m64' --enable-dtrace DTRACEFLAGS='-64' ...
```

Using Sun's compiler:

```
./configure CC='/opt/SUNWspro/bin/cc -xtarget=native64' --enable-dtrace DTRACEFLA
```

`--enable-tap-tests`

Enable tests using the Perl TAP tools. This requires a Perl installation and the Perl module `IPC::Run`. See Section 30.4 for more information.

If you prefer a C compiler different from the one `configure` picks, you can set the environment variable `CC` to the program of your choice. By default, `configure` will pick `gcc` if available, else the platform's default (usually `cc`). Similarly, you can override the default compiler flags if needed with the `CFLAGS` variable.

You can specify environment variables on the `configure` command line, for example:

```
./configure CC=/opt/bin/gcc CFLAGS='-O2 -pipe'
```

Here is a list of the significant variables that can be set in this manner:

`BISON`

Bison program

`CC`

C compiler

`CFLAGS`

options to pass to the C compiler

`CPP`

C preprocessor

`CPPFLAGS`

options to pass to the C preprocessor

`DTRACE`

location of the `dtrace` program

`DTRACEFLAGS`

options to pass to the `dtrace` program

`FLEX`

Flex program

`LDFLAGS`

options to use when linking either executables or shared libraries

`LDFLAGS_EX`

additional options for linking executables only

`LDFLAGS_SL`

additional options for linking shared libraries only

`MSGFMT`

`msgfmt` program for native language support

`PERL`

Full path to the Perl interpreter. This will be used to determine the dependencies for building PL/Perl.

`PYTHON`

Full path to the Python interpreter. This will be used to determine the dependencies for building PL/Python. Also, whether Python 2 or 3 is specified here (or otherwise implicitly chosen) determines which variant of the PL/Python language becomes available. See Section 43.1 for more information.

`TCLSH`

Full path to the Tcl interpreter. This will be used to determine the dependencies for building PL/Tcl, and it will be substituted into Tcl scripts.

`XML2_CONFIG`

`xml2-config` program used to locate the libxml installation.

Note: When developing code inside the server, it is recommended to use the configure options `--enable-cassert` (which turns on many run-time error checks) and `--enable-debug` (which improves the usefulness of debugging tools).

If using GCC, it is best to build with an optimization level of at least `-O1`, because using no optimization (`-O0`) disables some important compiler warnings (such as the use of uninitialized variables). However, non-zero optimization levels can complicate debugging because stepping through compiled code will usually not match up one-to-one with source code lines.

If you get confused while trying to debug optimized code, recompile the specific files of interest with `-O0`. An easy way to do this is by passing an option to make: `make PROFILE=-O0 file.o`.

2. Build

   To start the build, type:

   ```
   make
   ```

   (Remember to use GNU make.) The build will take a few minutes depending on your hardware. The last line displayed should be:

   ```
   All of PostgreSQL is successfully made. Ready to install.
   ```

   If you want to build everything that can be built, including the documentation (HTML and man pages), and the additional modules (`contrib`), type instead:

   ```
   make world
   ```

   The last line displayed should be:

   ```
   PostgreSQL, contrib and HTML documentation successfully made. Ready to install.
   ```

3. Regression Tests

   If you want to test the newly built server before you install it, you can run the regression tests at this point. The regression tests are a test suite to verify that PostgreSQL runs on your machine in the way the developers expected it to. Type:

   ```
   make check
   ```

   (This won't work as root; do it as an unprivileged user.) Chapter 30 contains detailed information about interpreting the test results. You can repeat this test at any later time by issuing the same command.

4. Installing the Files

   Note: If you are upgrading an existing system be sure to read Section 17.6 which has instructions about upgrading a cluster.

   To install PostgreSQL enter:

   ```
   make install
   ```

   This will install files into the directories that were specified in step 1. Make sure that you have appropriate permissions to write into that area. Normally you need to do this step as root. Alternatively, you can create the target directories in advance and arrange for appropriate permissions to be granted.

   To install the documentation (HTML and man pages), enter:

   ```
   make install-docs
   ```

   If you built the world above, type instead:

   ```
   make install-world
   ```

   This also installs the documentation.

   You can use `make install-strip` instead of `make install` to strip the executable files and libraries as they are installed. This will save some space. If you built with debugging support, stripping will effectively remove the debugging support, so it should only be done if debugging is no longer needed. `install-strip` tries to do a reasonable job saving space, but it does not

have perfect knowledge of how to strip every unneeded byte from an executable file, so if you want to save all the disk space you possibly can, you will have to do manual work.

The standard installation provides all the header files needed for client application development as well as for server-side program development, such as custom functions or data types written in C. (Prior to PostgreSQL 8.0, a separate `make install-all-headers` command was needed for the latter, but this step has been folded into the standard install.)

Client-only installation: If you want to install only the client applications and interface libraries, then you can use these commands:

```
make -C src/bin install
make -C src/include install
make -C src/interfaces install
make -C doc install
```

`src/bin` has a few binaries for server-only use, but they are small.

Uninstallation: To undo the installation use the command `make uninstall`. However, this will not remove any created directories.

Cleaning: After the installation you can free disk space by removing the built files from the source tree with the command `make clean`. This will preserve the files made by the `configure` program, so that you can rebuild everything with `make` later on. To reset the source tree to the state in which it was distributed, use `make distclean`. If you are going to build for several platforms within the same source tree you must do this and re-configure for each platform. (Alternatively, use a separate build tree for each platform, so that the source tree remains unmodified.)

If you perform a build and then discover that your `configure` options were wrong, or if you change anything that `configure` investigates (for example, software upgrades), then it's a good idea to do `make distclean` before reconfiguring and rebuilding. Without this, your changes in configuration choices might not propagate everywhere they need to.

15.5. Post-Installation Setup

15.5.1. Shared Libraries

On some systems with shared libraries you need to tell the system how to find the newly installed shared libraries. The systems on which this is *not* necessary include FreeBSD, HP-UX, Linux, NetBSD, OpenBSD, Tru64 UNIX (formerly Digital UNIX), and Solaris.

The method to set the shared library search path varies between platforms, but the most widely-used method is to set the environment variable `LD_LIBRARY_PATH` like so: In Bourne shells (`sh`, `ksh`, `bash`, `zsh`):

```
LD_LIBRARY_PATH=/usr/local/pgsql/lib
export LD_LIBRARY_PATH
```

or in `csh` or `tcsh`:

```
setenv LD_LIBRARY_PATH /usr/local/pgsql/lib
```

Replace `/usr/local/pgsql/lib` with whatever you set `--libdir` to in step 1. You should put these commands into a shell start-up file such as `/etc/profile` or `~/.bash_profile`.

Some good information about the caveats associated with this method can be found at http://xahlee.org/UnixResource_dir/_/ldpath.html.

On some systems it might be preferable to set the environment variable `LD_RUN_PATH` *before* building.

On Cygwin, put the library directory in the `PATH` or move the `.dll` files into the `bin` directory.

If in doubt, refer to the manual pages of your system (perhaps `ld.so` or `rld`). If you later get a message like:

```
psql: error in loading shared libraries
libpq.so.2.1: cannot open shared object file: No such file or directory
```

then this step was necessary. Simply take care of it then.

If you are on Linux and you have root access, you can run:

```
/sbin/ldconfig /usr/local/pgsql/lib
```

(or equivalent directory) after installation to enable the run-time linker to find the shared libraries faster. Refer to the manual page of `ldconfig` for more information. On FreeBSD, NetBSD, and OpenBSD the command is:

```
/sbin/ldconfig -m /usr/local/pgsql/lib
```

instead. Other systems are not known to have an equivalent command.

15.5.2. Environment Variables

If you installed into `/usr/local/pgsql` or some other location that is not searched for programs by default, you should add `/usr/local/pgsql/bin` (or whatever you set `--bindir` to in step 1) into your `PATH`. Strictly speaking, this is not necessary, but it will make the use of PostgreSQL much more convenient.

To do this, add the following to your shell start-up file, such as `~/.bash_profile` (or `/etc/profile`, if you want it to affect all users):

```
PATH=/usr/local/pgsql/bin:$PATH
export PATH
```

If you are using `csh` or `tcsh`, then use this command:

```
set path = ( /usr/local/pgsql/bin $path )
```

To enable your system to find the man documentation, you need to add lines like the following to a shell start-up file unless you installed into a location that is searched by default:

```
MANPATH=/usr/local/pgsql/man:$MANPATH
export MANPATH
```

The environment variables `PGHOST` and `PGPORT` specify to client applications the host and port of the database server, overriding the compiled-in defaults. If you are going to run client applications remotely then it is convenient if every user that plans to use the database sets `PGHOST`. This is not

required, however; the settings can be communicated via command line options to most client programs.

15.6. Supported Platforms

A platform (that is, a CPU architecture and operating system combination) is considered supported by the PostgreSQL development community if the code contains provisions to work on that platform and it has recently been verified to build and pass its regression tests on that platform. Currently, most testing of platform compatibility is done automatically by test machines in the PostgreSQL Build Farm[2]. If you are interested in using PostgreSQL on a platform that is not represented in the build farm, but on which the code works or can be made to work, you are strongly encouraged to set up a build farm member machine so that continued compatibility can be assured.

In general, PostgreSQL can be expected to work on these CPU architectures: x86, x86_64, IA64, PowerPC, PowerPC 64, S/390, S/390x, Sparc, Sparc 64, Alpha, ARM, MIPS, MIPSEL, M68K, and PA-RISC. Code support exists for M32R and VAX, but these architectures are not known to have been tested recently. It is often possible to build on an unsupported CPU type by configuring with `--disable-spinlocks`, but performance will be poor.

PostgreSQL can be expected to work on these operating systems: Linux (all recent distributions), Windows (Win2000 SP4 and later), FreeBSD, OpenBSD, NetBSD, OS X, AIX, HP/UX, Solaris, Tru64 Unix, and UnixWare. Other Unix-like systems may also work but are not currently being tested. In most cases, all CPU architectures supported by a given operating system will work. Look in the Section 15.7 below to see if there is information specific to your operating system, particularly if using an older system.

If you have installation problems on a platform that is known to be supported according to recent build farm results, please report it to <`pgsql-bugs@postgresql.org`>. If you are interested in porting PostgreSQL to a new platform, <`pgsql-hackers@postgresql.org`> is the appropriate place to discuss that.

15.7. Platform-specific Notes

This section documents additional platform-specific issues regarding the installation and setup of PostgreSQL. Be sure to read the installation instructions, and in particular Section 15.2 as well. Also, check Chapter 30 regarding the interpretation of regression test results.

Platforms that are not covered here have no known platform-specific installation issues.

15.7.1. AIX

PostgreSQL works on AIX, but getting it installed properly can be challenging. AIX versions from 4.3.3 to 6.1 are considered supported. You can use GCC or the native IBM compiler `xlc`. In general, using recent versions of AIX and PostgreSQL helps. Check the build farm for up to date information about which versions of AIX are known to work.

The minimum recommended fix levels for supported AIX versions are:

2. http://buildfarm.postgresql.org/

AIX 4.3.3

Maintenance Level 11 + post ML11 bundle

AIX 5.1

Maintenance Level 9 + post ML9 bundle

AIX 5.2

Technology Level 10 Service Pack 3

AIX 5.3

Technology Level 7

AIX 6.1

Base Level

To check your current fix level, use `oslevel -r` in AIX 4.3.3 to AIX 5.2 ML 7, or `oslevel -s` in later versions.

Use the following `configure` flags in addition to your own if you have installed Readline or libz in `/usr/local`: `--with-includes=/usr/local/include --with-libraries=/usr/local/lib`.

15.7.1.1. GCC Issues

On AIX 5.3, there have been some problems getting PostgreSQL to compile and run using GCC.

You will want to use a version of GCC subsequent to 3.3.2, particularly if you use a prepackaged version. We had good success with 4.0.1. Problems with earlier versions seem to have more to do with the way IBM packaged GCC than with actual issues with GCC, so that if you compile GCC yourself, you might well have success with an earlier version of GCC.

15.7.1.2. Unix-Domain Sockets Broken

AIX 5.3 has a problem where `sockaddr_storage` is not defined to be large enough. In version 5.3, IBM increased the size of `sockaddr_un`, the address structure for Unix-domain sockets, but did not correspondingly increase the size of `sockaddr_storage`. The result of this is that attempts to use Unix-domain sockets with PostgreSQL lead to libpq overflowing the data structure. TCP/IP connections work OK, but not Unix-domain sockets, which prevents the regression tests from working.

The problem was reported to IBM, and is recorded as bug report PMR29657. If you upgrade to maintenance level 5300-03 or later, that will include this fix. A quick workaround is to alter `_SS_MAXSIZE` to 1025 in `/usr/include/sys/socket.h`. In either case, recompile PostgreSQL once you have the corrected header file.

15.7.1.3. Internet Address Issues

PostgreSQL relies on the system's `getaddrinfo` function to parse IP addresses in `listen_addresses`, `pg_hba.conf`, etc. Older versions of AIX have assorted bugs in this function. If you have problems related to these settings, updating to the appropriate AIX fix level shown above should take care of it.

One user reports:

When implementing PostgreSQL version 8.1 on AIX 5.3, we periodically ran into problems where the statistics collector would "mysteriously" not come up successfully. This appears to be the result

of unexpected behavior in the IPv6 implementation. It looks like PostgreSQL and IPv6 do not play very well together on AIX 5.3.

Any of the following actions "fix" the problem.

- Delete the IPv6 address for localhost:

  ```
  (as root)
  # ifconfig lo0 inet6 ::1/0 delete
  ```

- Remove IPv6 from net services. The file `/etc/netsvc.conf` on AIX is roughly equivalent to `/etc/nsswitch.conf` on Solaris/Linux. The default, on AIX, is thus:

  ```
  hosts=local,bind
  ```

  Replace this with:

  ```
  hosts=local4,bind4
  ```

  to deactivate searching for IPv6 addresses.

> **Warning**
>
> This is really a workaround for problems relating to immaturity of IPv6 support, which improved visibly during the course of AIX 5.3 releases. It has worked with AIX version 5.3, but does not represent an elegant solution to the problem. It has been reported that this workaround is not only unnecessary, but causes problems on AIX 6.1, where IPv6 support has become more mature.

15.7.1.4. Memory Management

AIX can be somewhat peculiar with regards to the way it does memory management. You can have a server with many multiples of gigabytes of RAM free, but still get out of memory or address space errors when running applications. One example is `createlang` failing with unusual errors. For example, running as the owner of the PostgreSQL installation:

```
-bash-3.00$ createlang plperl template1
createlang: language installation failed: ERROR:  could not load library "/opt/dbs/pgsql
```

Running as a non-owner in the group possessing the PostgreSQL installation:

```
-bash-3.00$ createlang plperl template1
createlang: language installation failed: ERROR:  could not load library "/opt/dbs/pgsql
```

Another example is out of memory errors in the PostgreSQL server logs, with every memory allocation near or greater than 256 MB failing.

The overall cause of all these problems is the default bittedness and memory model used by the server process. By default, all binaries built on AIX are 32-bit. This does not depend upon hardware type or kernel in use. These 32-bit processes are limited to 4 GB of memory laid out in 256 MB segments using one of a few models. The default allows for less than 256 MB in the heap as it shares a single segment with the stack.

In the case of the `createlang` example, above, check your umask and the permissions of the binaries in your PostgreSQL installation. The binaries involved in that example were 32-bit and installed as mode 750 instead of 755. Due to the permissions being set in this fashion, only the owner or a member of the possessing group can load the library. Since it isn't world-readable, the loader places the object into the process' heap instead of the shared library segments where it would otherwise be placed.

The "ideal" solution for this is to use a 64-bit build of PostgreSQL, but that is not always practical, because systems with 32-bit processors can build, but not run, 64-bit binaries.

If a 32-bit binary is desired, set `LDR_CNTRL` to `MAXDATA=0x`*n*`0000000`, where 1 <= n <= 8, before starting the PostgreSQL server, and try different values and `postgresql.conf` settings to find a configuration that works satisfactorily. This use of `LDR_CNTRL` tells AIX that you want the server to have `MAXDATA` bytes set aside for the heap, allocated in 256 MB segments. When you find a workable configuration, `ldedit` can be used to modify the binaries so that they default to using the desired heap size. PostgreSQL can also be rebuilt, passing `configure LDFLAGS="-Wl,-bmaxdata:0x`*n*`0000000"` to achieve the same effect.

For a 64-bit build, set `OBJECT_MODE` to 64 and pass `CC="gcc -maix64"` and `LDFLAGS="-Wl,-bbigtoc"` to `configure`. (Options for `xlc` might differ.) If you omit the export of `OBJECT_MODE`, your build may fail with linker errors. When `OBJECT_MODE` is set, it tells AIX's build utilities such as `ar`, `as`, and `ld` what type of objects to default to handling.

By default, overcommit of paging space can happen. While we have not seen this occur, AIX will kill processes when it runs out of memory and the overcommit is accessed. The closest to this that we have seen is fork failing because the system decided that there was not enough memory for another process. Like many other parts of AIX, the paging space allocation method and out-of-memory kill is configurable on a system- or process-wide basis if this becomes a problem.

References and Resources

"Large Program Support[1]", *AIX Documentation: General Programming Concepts: Writing and Debugging Programs*.

"Program Address Space Overview[2]", *AIX Documentation: General Programming Concepts: Writing and Debugging Programs*.

"Performance Overview of the Virtual Memory Manager (VMM)[3]", *AIX Documentation: Performance Management Guide*.

"Page Space Allocation[4]", *AIX Documentation: Performance Management Guide*.

"Paging-space thresholds tuning[5]", *AIX Documentation: Performance Management Guide*.

Developing and Porting C and C++ Applications on AIX[6], IBM Redbook.

15.7.2. Cygwin

PostgreSQL can be built using Cygwin, a Linux-like environment for Windows, but that method is inferior to the native Windows build (see Chapter 16) and running a server under Cygwin is no longer recommended.

When building from source, proceed according to the normal installation procedure (i.e., `./configure; make`; etc.), noting the following-Cygwin specific differences:

1. http://publib.boulder.ibm.com/infocenter/pseries/topic/com.ibm.aix.doc/aixprggd/genprogc/lrg_prg_support.htm
2. http://publib.boulder.ibm.com/infocenter/pseries/topic/com.ibm.aix.doc/aixprggd/genprogc/address_space.htm
3. http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/resmgmt2.htm
4. http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/memperf7.htm
5. http://publib.boulder.ibm.com/infocenter/pseries/v5r3/topic/com.ibm.aix.doc/aixbman/prftungd/memperf6.htm
6. http://www.redbooks.ibm.com/abstracts/sg245674.html?Open

- Set your path to use the Cygwin bin directory before the Windows utilities. This will help prevent problems with compilation.
- The `adduser` command is not supported; use the appropriate user management application on Windows NT, 2000, or XP. Otherwise, skip this step.
- The `su` command is not supported; use ssh to simulate su on Windows NT, 2000, or XP. Otherwise, skip this step.
- OpenSSL is not supported.
- Start `cygserver` for shared memory support. To do this, enter the command `/usr/sbin/cygserver &`. This program needs to be running anytime you start the PostgreSQL server or initialize a database cluster (`initdb`). The default `cygserver` configuration may need to be changed (e.g., increase `SEMMNS`) to prevent PostgreSQL from failing due to a lack of system resources.
- Building might fail on some systems where a locale other than C is in use. To fix this, set the locale to C by doing `export LANG=C.utf8` before building, and then setting it back to the previous setting, after you have installed PostgreSQL.
- The parallel regression tests (`make check`) can generate spurious regression test failures due to overflowing the `listen()` backlog queue which causes connection refused errors or hangs. You can limit the number of connections using the make variable `MAX_CONNECTIONS` thus:

  ```
  make MAX_CONNECTIONS=5 check
  ```

  (On some systems you can have up to about 10 simultaneous connections).

It is possible to install `cygserver` and the PostgreSQL server as Windows NT services. For information on how to do this, please refer to the `README` document included with the PostgreSQL binary package on Cygwin. It is installed in the directory `/usr/share/doc/Cygwin`.

15.7.3. HP-UX

PostgreSQL 7.3+ should work on Series 700/800 PA-RISC machines running HP-UX 10.X or 11.X, given appropriate system patch levels and build tools. At least one developer routinely tests on HP-UX 10.20, and we have reports of successful installations on HP-UX 11.00 and 11.11.

Aside from the PostgreSQL source distribution, you will need GNU make (HP's make will not do), and either GCC or HP's full ANSI C compiler. If you intend to build from Git sources rather than a distribution tarball, you will also need Flex (GNU lex) and Bison (GNU yacc). We also recommend making sure you are fairly up-to-date on HP patches. At a minimum, if you are building 64 bit binaries on HP-UX 11.11 you may need PHSS_30966 (11.11) or a successor patch otherwise `initdb` may hang:

PHSS_30966 s700_800 ld(1) and linker tools cumulative patch

On general principles you should be current on libc and ld/dld patches, as well as compiler patches if you are using HP's C compiler. See HP's support sites such as http://itrc.hp.com and ftp://us-ffs.external.hp.com/ for free copies of their latest patches.

If you are building on a PA-RISC 2.0 machine and want to have 64-bit binaries using GCC, you must use GCC 64-bit version. GCC binaries for HP-UX PA-RISC and Itanium are available from http://www.hp.com/go/gcc. Don't forget to get and install binutils at the same time.

If you are building on a PA-RISC 2.0 machine and want the compiled binaries to run on PA-RISC 1.1 machines you will need to specify `+DAportable` in `CFLAGS`.

If you are building on a HP-UX Itanium machine, you will need the latest HP ANSI C compiler with its dependent patch or successor patches:

PHSS_30848 s700_800 HP C Compiler (A.05.57)
PHSS_30849 s700_800 u2comp/be/plugin library Patch

If you have both HP's C compiler and GCC's, then you might want to explicitly select the compiler to use when you run `configure`:

```
./configure CC=cc
```

for HP's C compiler, or

```
./configure CC=gcc
```

for GCC. If you omit this setting, then configure will pick `gcc` if it has a choice.

The default install target location is `/usr/local/pgsql`, which you might want to change to something under `/opt`. If so, use the `--prefix` switch to `configure`.

In the regression tests, there might be some low-order-digit differences in the geometry tests, which vary depending on which compiler and math library versions you use. Any other error is cause for suspicion.

15.7.4. MinGW/Native Windows

PostgreSQL for Windows can be built using MinGW, a Unix-like build environment for Microsoft operating systems, or using Microsoft's Visual C++ compiler suite. The MinGW build variant uses the normal build system described in this chapter; the Visual C++ build works completely differently and is described in Chapter 16. It is a fully native build and uses no additional software like MinGW. A ready-made installer is available on the main PostgreSQL web site.

The native Windows port requires a 32 or 64-bit version of Windows 2000 or later. Earlier operating systems do not have sufficient infrastructure (but Cygwin may be used on those). MinGW, the Unix-like build tools, and MSYS, a collection of Unix tools required to run shell scripts like `configure`, can be downloaded from http://www.mingw.org/. Neither is required to run the resulting binaries; they are needed only for creating the binaries.

To build 64 bit binaries using MinGW, install the 64 bit tool set from http://mingw-w64.sourceforge.net/, put its bin directory in the `PATH`, and run `configure` with the `--host=x86_64-w64-mingw` option.

After you have everything installed, it is suggested that you run psql under `CMD.EXE`, as the MSYS console has buffering issues.

15.7.4.1. Collecting Crash Dumps on Windows

If PostgreSQL on Windows crashes, it has the ability to generate minidumps that can be used to track down the cause for the crash, similar to core dumps on Unix. These dumps can be read using the Windows Debugger Tools or using Visual Studio. To enable the generation of dumps on Windows, create a subdirectory named `crashdumps` inside the cluster data directory. The dumps will then be written into this directory with a unique name based on the identifier of the crashing process and the current time of the crash.

15.7.5. SCO OpenServer and SCO UnixWare

PostgreSQL can be built on SCO UnixWare 7 and SCO OpenServer 5. On OpenServer, you can use either the OpenServer Development Kit or the Universal Development Kit. However, some tweaking may be needed, as described below.

15.7.5.1. Skunkware

You should locate your copy of the SCO Skunkware CD. The Skunkware CD is included with UnixWare 7 and current versions of OpenServer 5. Skunkware includes ready-to-install versions of many popular programs that are available on the Internet. For example, gzip, gunzip, GNU Make, Flex, and Bison are all included. For UnixWare 7.1, this CD is now labeled "Open License Software Supplement". If you do not have this CD, the software on it is available from http://www.sco.com/skunkware/.

Skunkware has different versions for UnixWare and OpenServer. Make sure you install the correct version for your operating system, except as noted below.

On UnixWare 7.1.3 and beyond, the GCC compiler is included on the UDK CD as is GNU Make.

15.7.5.2. GNU Make

You need to use the GNU Make program, which is on the Skunkware CD. By default, it installs as `/usr/local/bin/make`.

As of UnixWare 7.1.3 and above, the GNU Make program is the OSTK portion of the UDK CD, and is in `/usr/gnu/bin/gmake`.

15.7.5.3. Readline

The Readline library is on the Skunkware CD. But it is not included on the UnixWare 7.1 Skunkware CD. If you have the UnixWare 7.0.0 or 7.0.1 Skunkware CDs, you can install it from there. Otherwise, try http://www.sco.com/skunkware/.

By default, Readline installs into `/usr/local/lib` and `/usr/local/include`. However, the PostgreSQL `configure` program will not find it there without help. If you installed Readline, then use the following options to `configure`:

```
./configure --with-libraries=/usr/local/lib --with-includes=/usr/local/include
```

15.7.5.4. Using the UDK on OpenServer

If you are using the new Universal Development Kit (UDK) compiler on OpenServer, you need to specify the locations of the UDK libraries:

```
./configure --with-libraries=/udk/usr/lib --with-includes=/udk/usr/include
```

Putting these together with the Readline options from above:

```
./configure --with-libraries="/udk/usr/lib /usr/local/lib" --with-includes="/udk/usr/inc
```

15.7.5.5. Reading the PostgreSQL Man Pages

By default, the PostgreSQL man pages are installed into `/usr/local/pgsql/man`. By default, UnixWare does not look there for man pages. To be able to read them you need to modify the `MANPATH` variable in `/etc/default/man`, for example:

```
MANPATH=/usr/lib/scohelp/%L/man:/usr/dt/man:/usr/man:/usr/share/man:scohelp:/usr/local/m
```

On OpenServer, some extra research needs to be invested to make the man pages usable, because the man system is a bit different from other platforms. Currently, PostgreSQL will not install them at all.

15.7.5.6. C99 Issues with the 7.1.1b Feature Supplement

For compilers earlier than the one released with OpenUNIX 8.0.0 (UnixWare 7.1.2), including the 7.1.1b Feature Supplement, you may need to specify `-Xb` in `CFLAGS` or the `CC` environment variable. The indication of this is an error in compiling `tuplesort.c` referencing inline functions. Apparently there was a change in the 7.1.2(8.0.0) compiler and beyond.

15.7.5.7. Threading on UnixWare

For threading, you*must* use `-Kpthread` on *all* libpq-using programs. libpq uses `pthread_*` calls, which are only available with the `-Kpthread`/`-Kthread` flag.

15.7.6. Solaris

PostgreSQL is well-supported on Solaris. The more up to date your operating system, the fewer issues you will experience; details below.

15.7.6.1. Required Tools

You can build with either GCC or Sun's compiler suite. For better code optimization, Sun's compiler is strongly recommended on the SPARC architecture. We have heard reports of problems when using GCC 2.95.1; GCC 2.95.3 or later is recommended. If you are using Sun's compiler, be careful not to select `/usr/ucb/cc`; use `/opt/SUNWspro/bin/cc`.

You can download Sun Studio from http://www.oracle.com/technetwork/server-storage/solarisstudio/downloads/. Many of GNU tools are integrated into Solaris 10, or they are present on the Solaris companion CD. If you like packages for older version of Solaris, you can find these tools at http://www.sunfreeware.com. If you prefer sources, look at http://www.gnu.org/order/ftp.html.

15.7.6.2. Problems with OpenSSL

When you build PostgreSQL with OpenSSL support you might get compilation errors in the following files:

- `src/backend/libpq/crypt.c`
- `src/backend/libpq/password.c`

- src/interfaces/libpq/fe-auth.c
- src/interfaces/libpq/fe-connect.c

This is because of a namespace conflict between the standard /usr/include/crypt.h header and the header files provided by OpenSSL.

Upgrading your OpenSSL installation to version 0.9.6a fixes this problem. Solaris 9 and above has a newer version of OpenSSL.

15.7.6.3. configure Complains About a Failed Test Program

If configure complains about a failed test program, this is probably a case of the run-time linker being unable to find some library, probably libz, libreadline or some other non-standard library such as libssl. To point it to the right location, set the LDFLAGS environment variable on the configure command line, e.g.,

```
configure ... LDFLAGS="-R /usr/sfw/lib:/opt/sfw/lib:/usr/local/lib"
```

See the ld man page for more information.

15.7.6.4. 64-bit Build Sometimes Crashes

On Solaris 7 and older, the 64-bit version of libc has a buggy vsnprintf routine, which leads to erratic core dumps in PostgreSQL. The simplest known workaround is to force PostgreSQL to use its own version of vsnprintf rather than the library copy. To do this, after you run configure edit a file produced by configure: In src/Makefile.global, change the line

```
LIBOBJS =
```

to read

```
LIBOBJS = snprintf.o
```

(There might be other files already listed in this variable. Order does not matter.) Then build as usual.

15.7.6.5. Compiling for Optimal Performance

On the SPARC architecture, Sun Studio is strongly recommended for compilation. Try using the -xO5 optimization flag to generate significantly faster binaries. Do not use any flags that modify behavior of floating-point operations and errno processing (e.g., -fast). These flags could raise some nonstandard PostgreSQL behavior for example in the date/time computing.

If you do not have a reason to use 64-bit binaries on SPARC, prefer the 32-bit version. The 64-bit operations are slower and 64-bit binaries are slower than the 32-bit variants. And on other hand, 32-bit code on the AMD64 CPU family is not native, and that is why 32-bit code is significant slower on this CPU family.

15.7.6.6. Using DTrace for Tracing PostgreSQL

Yes, using DTrace is possible. See Section 27.4 for further information. You can also find more information in this article: https://blogs.oracle.com/robertlor/entry/user_level_dtrace_probes_in.

If you see the linking of the postgres executable abort with an error message like:

```
Undefined                       first referenced
 symbol                             in file
AbortTransaction                   utils/probes.o
CommitTransaction                  utils/probes.o
ld: fatal: Symbol referencing errors. No output written to postgres
collect2: ld returned 1 exit status
make: *** [postgres] Error 1
```

your DTrace installation is too old to handle probes in static functions. You need Solaris 10u4 or newer.

Chapter 16. Installation from Source Code on Windows

It is recommended that most users download the binary distribution for Windows, available as a graphical installer package from the PostgreSQL website. Building from source is only intended for people developing PostgreSQL or extensions.

There are several different ways of building PostgreSQL on Windows. The simplest way to build with Microsoft tools is to install Visual Studio Express 2013 for Windows Desktop and use the included compiler. It is also possible to build with the full Microsoft Visual C++ 2005 to 2013. In some cases that requires the installation of the Windows SDK in addition to the compiler.

It is also possible to build PostgreSQL using the GNU compiler tools provided by MinGW, or using Cygwin for older versions of Windows.

Finally, the client access library (libpq) can be built using Visual C++ 7.1 or Borland C++ for compatibility with statically linked applications built using these tools.

Building using MinGW or Cygwin uses the normal build system, see Chapter 15 and the specific notes in Section 15.7.4 and Section 15.7.2. To produce native 64 bit binaries in these environments, use the tools from MinGW-w64. These tools can also be used to cross-compile for 32 bit and 64 bit Windows targets on other hosts, such as Linux and Darwin. Cygwin is not recommended for running a production server, and it should only be used for running on older versions of Windows where the native build does not work, such as Windows 98. The official binaries are built using Visual Studio.

Native builds of psql don't support command line editing. The Cygwin build does support command line editing, so it should be used where psql is needed for interactive use on Windows.

16.1. Building with Visual C++ or the Microsoft Windows SDK

PostgreSQL can be built using the Visual C++ compiler suite from Microsoft. These compilers can be either from Visual Studio, Visual Studio Express or some versions of the Microsoft Windows SDK. If you do not already have a Visual Studio environment set up, the easiest ways are to use the compilers from Visual Studio Express 2013 for Windows Desktop or those in the Windows SDK 7.1, which are both free downloads from Microsoft.

PostgreSQL is known to support compilation using the compilers shipped with Visual Studio 2005 to Visual Studio 2013 (including Express editions), as well as standalone Windows SDK releases 6.0 to 7.1. 64-bit PostgreSQL builds are only supported with Microsoft Windows SDK version 6.0a to 7.1 or Visual Studio 2008 and above.

The tools for building using Visual C++ or Platform SDK are in the `src/tools/msvc` directory. When building, make sure there are no tools from MinGW or Cygwin present in your system PATH. Also, make sure you have all the required Visual C++ tools available in the PATH. In Visual Studio, start the Visual Studio Command Prompt. If you wish to build a 64-bit version, you must use the 64-bit version of the command, and vice versa. In the Microsoft Windows SDK, start the CMD shell listed under the SDK on the Start Menu. In recent SDK versions you can change the targeted CPU architecture, build type, and target OS by using the `setenv` command, e.g. `setenv /x86 /release /xp` to target Windows XP or later with a 32-bit release build. See `/?` for other options to `setenv`. All commands should be run from the `src\tools\msvc` directory.

Before you build, you may need to edit the file `config.pl` to reflect any configuration options you want to change, or the paths to any third party libraries to use. The complete configuration is determined by first reading and parsing the file `config_default.pl`, and then apply any changes from `config.pl`. For example, to specify the location of your Python installation, put the following in `config.pl`:

```
$config->{python} = 'c:\python26';
```

You only need to specify those parameters that are different from what's in `config_default.pl`.

If you need to set any other environment variables, create a file called `buildenv.pl` and put the required commands there. For example, to add the path for bison when it's not in the PATH, create a file containing:

```
$ENV{PATH}=$ENV{PATH} . ';c:\some\where\bison\bin';
```

16.1.1. Requirements

The following additional products are required to build PostgreSQL. Use the `config.pl` file to specify which directories the libraries are available in.

Microsoft Windows SDK

If your build environment doesn't ship with a supported version of the Microsoft Windows SDK it is recommended that you upgrade to the latest version (currently version 7.1), available for download from http://www.microsoft.com/downloads/.

You must always include the Windows Headers and Libraries part of the SDK. If you install a Windows SDK including the Visual C++ Compilers, you don't need Visual Studio to build. Note that as of Version 8.0a the Windows SDK no longer ships with a complete command-line build environment.

ActiveState Perl

ActiveState Perl is required to run the build generation scripts. MinGW or Cygwin Perl will not work. It must also be present in the PATH. Binaries can be downloaded from http://www.activestate.com (Note: version 5.8 or later is required, the free Standard Distribution is sufficient).

The following additional products are not required to get started, but are required to build the complete package. Use the `config.pl` file to specify which directories the libraries are available in.

ActiveState TCL

Required for building PL/TCL (Note: version 8.4 is required, the free Standard Distribution is sufficient).

Bison and Flex

Bison and Flex are required to build from Git, but not required when building from a release file. Only Bison 1.875 or versions 2.2 and later will work. Flex must be version 2.5.31 or later.

Both Bison and Flex are included in the msys tool suite, available from http://www.mingw.org/wiki/MSYS as part of the MinGW compiler suite. You can also get msys as part of msysGit from http://git-scm.com/.

You will need to add the directory containing `flex.exe` and `bison.exe` to the PATH environment variable in `buildenv.pl` unless they are already in PATH. In the case of MinGW, the directory is the `\msys\1.0\bin` subdirectory of your MinGW installation directory. For msysGit, it's the `bin` directory in your Git install directory. Do not add the MinGW compiler tools themselves to PATH.

> **Note:** The Bison distribution from GnuWin32 appears to have a bug that causes Bison to malfunction when installed in a directory with spaces in the name, such as the default location on English installations `C:\Program Files\GnuWin32`. Consider installing into `C:\GnuWin32` or use the NTFS short name path to GnuWin32 in your PATH environment setting (e.g. `C:\PROGRA~1\GnuWin32`).

> **Note:** The obsolete "winflex" binaries distributed on the PostgreSQL FTP site and referenced in older documentation will fail with "flex: fatal internal error, exec failed" on 64-bit Windows hosts. Use flex from msys instead.

Diff

Diff is required to run the regression tests, and can be downloaded from http://gnuwin32.sourceforge.net.

Gettext

Gettext is required to build with NLS support, and can be downloaded from http://gnuwin32.sourceforge.net. Note that binaries, dependencies and developer files are all needed.

MIT Kerberos

Required for GSSAPI authentication support. MIT Kerberos can be downloaded from http://web.mit.edu/Kerberos/dist/index.html.

libxml2 and libxslt

Required for XML support. Binaries can be downloaded from http://zlatkovic.com/pub/libxml or source from http://xmlsoft.org. Note that libxml2 requires iconv, which is available from the same download location.

openssl

Required for SSL support. Binaries can be downloaded from http://www.slproweb.com/products/Win32OpenSSL.html or source from http://www.openssl.org.

ossp-uuid

Required for UUID-OSSP support (contrib only). Source can be downloaded from http://www.ossp.org/pkg/lib/uuid/.

Python

Required for building PL/Python. Binaries can be downloaded from http://www.python.org.

zlib

Required for compression support in pg_dump and pg_restore. Binaries can be downloaded from http://www.zlib.net.

16.1.2. Special Considerations for 64-bit Windows

PostgreSQL will only build for the x64 architecture on 64-bit Windows, there is no support for Itanium processors.

Mixing 32- and 64-bit versions in the same build tree is not supported. The build system will automatically detect if it's running in a 32- or 64-bit environment, and build PostgreSQL accordingly. For this reason, it is important to start the correct command prompt before building.

To use a server-side third party library such as python or openssl, this library *must* also be 64-bit. There is no support for loading a 32-bit library in a 64-bit server. Several of the third party libraries that PostgreSQL supports may only be available in 32-bit versions, in which case they cannot be used with 64-bit PostgreSQL.

16.1.3. Building

To build all of PostgreSQL in release configuration (the default), run the command:

```
build
```

To build all of PostgreSQL in debug configuration, run the command:

```
build DEBUG
```

To build just a single project, for example psql, run the commands:

```
build psql
build DEBUG psql
```

To change the default build configuration to debug, put the following in the `buildenv.pl` file:

```
$ENV{CONFIG}="Debug";
```

It is also possible to build from inside the Visual Studio GUI. In this case, you need to run:

```
perl mkvcbuild.pl
```

from the command prompt, and then open the generated `pgsql.sln` (in the root directory of the source tree) in Visual Studio.

16.1.4. Cleaning and Installing

Most of the time, the automatic dependency tracking in Visual Studio will handle changed files. But if there have been large changes, you may need to clean the installation. To do this, simply run the `clean.bat` command, which will automatically clean out all generated files. You can also run it with the `dist` parameter, in which case it will behave like **`make distclean`** and remove the flex/bison output files as well.

By default, all files are written into a subdirectory of the `debug` or `release` directories. To install these files using the standard layout, and also generate the files required to initialize and use the database, run the command:

```
install c:\destination\directory
```

If you want to install only the client applications and interface libraries, then you can use these commands:

```
install c:\destination\directory client
```

16.1.5. Running the Regression Tests

To run the regression tests, make sure you have completed the build of all required parts first. Also, make sure that the DLLs required to load all parts of the system (such as the Perl and Python DLLs for the procedural languages) are present in the system path. If they are not, set it through the `buildenv.pl` file. To run the tests, run one of the following commands from the `src\tools\msvc` directory:

```
vcregress check
vcregress installcheck
vcregress plcheck
vcregress contribcheck
vcregress ecpgcheck
vcregress isolationcheck
vcregress upgradecheck
```

To change the schedule used (default is parallel), append it to the command line like:

```
vcregress check serial
```

For more information about the regression tests, see Chapter 30.

16.1.6. Building the Documentation

Building the PostgreSQL documentation in HTML format requires several tools and files. Create a root directory for all these files, and store them in the subdirectories in the list below.

OpenJade 1.3.1-2

Download from http://sourceforge.net/projects/openjade/files/openjade/1.3.1/openjade-1_3_1-2-bin.zip/download and uncompress in the subdirectory `openjade-1.3.1`.

DocBook DTD 4.2

Download from http://www.oasis-open.org/docbook/sgml/4.2/docbook-4.2.zip and uncompress in the subdirectory `docbook`.

DocBook DSSSL 1.79

Download from http://sourceforge.net/projects/docbook/files/docbook-dsssl/1.79/docbook-dsssl-1.79.zip/download and uncompress in the subdirectory `docbook-dsssl-1.79`.

ISO character entities

Download from http://www.oasis-open.org/cover/ISOEnts.zip and uncompress in the subdirectory `docbook`.

Edit the `buildenv.pl` file, and add a variable for the location of the root directory, for example:

```
$ENV{DOCROOT}='c:\docbook';
```

To build the documentation, run the command `builddoc.bat`. Note that this will actually run the build twice, in order to generate the indexes. The generated HTML files will be in `doc\src\sgml`.

16.2. Building libpq with Visual C++ or Borland C++

Using Visual C++ 7.1-9.0 or Borland C++ to build libpq is only recommended if you need a version with different debug/release flags, or if you need a static library to link into an application. For normal use the MinGW or Visual Studio or Windows SDK method is recommended.

To build the libpq client library using Visual Studio 7.1 or later, change into the `src` directory and type the command:

```
nmake /f win32.mak
```

To build a 64-bit version of the libpq client library using Visual Studio 8.0 or later, change into the `src` directory and type in the command:

```
nmake /f win32.mak CPU=AMD64
```

See the `win32.mak` file for further details about supported variables.

To build the libpq client library using Borland C++, change into the `src` directory and type the command:

```
make -N -DCFG=Release /f bcc32.mak
```

16.2.1. Generated Files

The following files will be built:

`interfaces\libpq\Release\libpq.dll`

The dynamically linkable frontend library

`interfaces\libpq\Release\libpqdll.lib`

Import library to link your programs to `libpq.dll`

`interfaces\libpq\Release\libpq.lib`

Static version of the frontend library

Normally you do not need to install any of the client files. You should place the `libpq.dll` file in the same directory as your applications executable file. Do not install `libpq.dll` into your `Windows`, `System` or `System32` directory unless absolutely necessary. If this file is installed using a setup program, then it should be installed with version checking using the `VERSIONINFO` resource included in the file, to ensure that a newer version of the library is not overwritten.

If you are planning to do development using libpq on this machine, you will have to add the `src\include` and `src\interfaces\libpq` subdirectories of the source tree to the include path in your compiler's settings.

To use the library, you must add the `libpqdll.lib` file to your project. (In Visual C++, just right-click on the project and choose to add it.)

Chapter 17. Server Setup and Operation

This chapter discusses how to set up and run the database server and its interactions with the operating system.

17.1. The PostgreSQL User Account

As with any server daemon that is accessible to the outside world, it is advisable to run PostgreSQL under a separate user account. This user account should only own the data that is managed by the server, and should not be shared with other daemons. (For example, using the user `nobody` is a bad idea.) It is not advisable to install executables owned by this user because compromised systems could then modify their own binaries.

To add a Unix user account to your system, look for a command `useradd` or `adduser`. The user name postgres is often used, and is assumed throughout this book, but you can use another name if you like.

17.2. Creating a Database Cluster

Before you can do anything, you must initialize a database storage area on disk. We call this a *database cluster*. (SQL uses the term catalog cluster.) A database cluster is a collection of databases that is managed by a single instance of a running database server. After initialization, a database cluster will contain a database named `postgres`, which is meant as a default database for use by utilities, users and third party applications. The database server itself does not require the `postgres` database to exist, but many external utility programs assume it exists. Another database created within each cluster during initialization is called `template1`. As the name suggests, this will be used as a template for subsequently created databases; it should not be used for actual work. (See Chapter 21 for information about creating new databases within a cluster.)

In file system terms, a database cluster will be a single directory under which all data will be stored. We call this the *data directory* or *data area*. It is completely up to you where you choose to store your data. There is no default, although locations such as `/usr/local/pgsql/data` or `/var/lib/pgsql/data` are popular. To initialize a database cluster, use the command initdb, which is installed with PostgreSQL. The desired file system location of your database cluster is indicated by the `-D` option, for example:

```
$ initdb -D /usr/local/pgsql/data
```

Note that you must execute this command while logged into the PostgreSQL user account, which is described in the previous section.

> **Tip:** As an alternative to the `-D` option, you can set the environment variable `PGDATA`.

Alternatively, you can run `initdb` via the pg_ctl program like so:

```
$ pg_ctl -D /usr/local/pgsql/data initdb
```

This may be more intuitive if you are using `pg_ctl` for starting and stopping the server (see Section 17.3), so that `pg_ctl` would be the sole command you use for managing the database server instance.

initdb will attempt to create the directory you specify if it does not already exist. It is likely that it will not have the permission to do so (if you followed our advice and created an unprivileged account). In that case you should create the directory yourself (as root) and change the owner to be the PostgreSQL user. Here is how this might be done:

```
root# mkdir /usr/local/pgsql/data
root# chown postgres /usr/local/pgsql/data
root# su postgres
postgres$ initdb -D /usr/local/pgsql/data
```

initdb will refuse to run if the data directory looks like it has already been initialized.

Because the data directory contains all the data stored in the database, it is essential that it be secured from unauthorized access. initdb therefore revokes access permissions from everyone but the PostgreSQL user.

However, while the directory contents are secure, the default client authentication setup allows any local user to connect to the database and even become the database superuser. If you do not trust other local users, we recommend you use one of initdb's -W, --pwprompt or --pwfile options to assign a password to the database superuser. Also, specify -A md5 or -A password so that the default trust authentication mode is not used; or modify the generated pg_hba.conf file after running initdb, but *before* you start the server for the first time. (Other reasonable approaches include using peer authentication or file system permissions to restrict connections. See Chapter 19 for more information.)

initdb also initializes the default locale for the database cluster. Normally, it will just take the locale settings in the environment and apply them to the initialized database. It is possible to specify a different locale for the database; more information about that can be found in Section 22.1. The default sort order used within the particular database cluster is set by initdb, and while you can create new databases using different sort order, the order used in the template databases that initdb creates cannot be changed without dropping and recreating them. There is also a performance impact for using locales other than C or POSIX. Therefore, it is important to make this choice correctly the first time.

initdb also sets the default character set encoding for the database cluster. Normally this should be chosen to match the locale setting. For details see Section 22.3.

17.2.1. Network File Systems

Many installations create database clusters on network file systems. Sometimes this is done directly via NFS, or by using a Network Attached Storage (NAS) device that uses NFS internally. PostgreSQL does nothing special for NFS file systems, meaning it assumes NFS behaves exactly like locally-connected drives (DAS, Direct Attached Storage). If client and server NFS implementations have non-standard semantics, this can cause reliability problems (see http://www.time-travellers.org/shane/papers/NFS_considered_harmful.html). Specifically, delayed (asynchronous) writes to the NFS server can cause reliability problems; if possible, mount NFS file systems synchronously (without caching) to avoid this. Also, soft-mounting NFS is not recommended. (Storage Area Networks (SAN) use a low-level communication protocol rather than NFS.)

17.3. Starting the Database Server

Before anyone can access the database, you must start the database server. The database server program is called `postgres`. The `postgres` program must know where to find the data it is supposed to use. This is done with the `-D` option. Thus, the simplest way to start the server is:

```
$ postgres -D /usr/local/pgsql/data
```

which will leave the server running in the foreground. This must be done while logged into the PostgreSQL user account. Without `-D`, the server will try to use the data directory named by the environment variable `PGDATA`. If that variable is not provided either, it will fail.

Normally it is better to start `postgres` in the background. For this, use the usual Unix shell syntax:

```
$ postgres -D /usr/local/pgsql/data >logfile 2>&1 &
```

It is important to store the server's stdout and stderr output somewhere, as shown above. It will help for auditing purposes and to diagnose problems. (See Section 23.3 for a more thorough discussion of log file handling.)

The `postgres` program also takes a number of other command-line options. For more information, see the postgres reference page and Chapter 18 below.

This shell syntax can get tedious quickly. Therefore the wrapper program pg_ctl is provided to simplify some tasks. For example:

```
pg_ctl start -l logfile
```

will start the server in the background and put the output into the named log file. The `-D` option has the same meaning here as for `postgres`. `pg_ctl` is also capable of stopping the server.

Normally, you will want to start the database server when the computer boots. Autostart scripts are operating-system-specific. There are a few distributed with PostgreSQL in the `contrib/start-scripts` directory. Installing one will require root privileges.

Different systems have different conventions for starting up daemons at boot time. Many systems have a file `/etc/rc.local` or `/etc/rc.d/rc.local`. Others use `init.d` or `rc.d` directories. Whatever you do, the server must be run by the PostgreSQL user account *and not by root* or any other user. Therefore you probably should form your commands using `su postgres -c '...'`. For example:

```
su postgres -c 'pg_ctl start -D /usr/local/pgsql/data -l serverlog'
```

Here are a few more operating-system-specific suggestions. (In each case be sure to use the proper installation directory and user name where we show generic values.)

- For FreeBSD, look at the file `contrib/start-scripts/freebsd` in the PostgreSQL source distribution.
- On OpenBSD, add the following lines to the file `/etc/rc.local`:

```
if [ -x /usr/local/pgsql/bin/pg_ctl -a -x /usr/local/pgsql/bin/postgres ]; then
    su -l postgres -c '/usr/local/pgsql/bin/pg_ctl start -s -l /var/postgresql/log -D
    echo -n ' postgresql'
fi
```

- On Linux systems either add

```
/usr/local/pgsql/bin/pg_ctl start -l logfile -D /usr/local/pgsql/data
```

to `/etc/rc.d/rc.local` or `/etc/rc.local` or look at the file `contrib/start-scripts/linux` in the PostgreSQL source distribution.

- On NetBSD, use either the FreeBSD or Linux start scripts, depending on preference.
- On Solaris, create a file called `/etc/init.d/postgresql` that contains the following line:

```
su - postgres -c "/usr/local/pgsql/bin/pg_ctl start -l logfile -D /usr/local/pgsql/dat
```

Then, create a symbolic link to it in `/etc/rc3.d` as `S99postgresql`.

While the server is running, its PID is stored in the file `postmaster.pid` in the data directory. This is used to prevent multiple server instances from running in the same data directory and can also be used for shutting down the server.

17.3.1. Server Start-up Failures

There are several common reasons the server might fail to start. Check the server's log file, or start it by hand (without redirecting standard output or standard error) and see what error messages appear. Below we explain some of the most common error messages in more detail.

```
LOG:  could not bind IPv4 socket: Address already in use
HINT:  Is another postmaster already running on port 5432? If not, wait a few seconds an
FATAL:  could not create TCP/IP listen socket
```

This usually means just what it suggests: you tried to start another server on the same port where one is already running. However, if the kernel error message is not `Address already in use` or some variant of that, there might be a different problem. For example, trying to start a server on a reserved port number might draw something like:

```
$ postgres -p 666
LOG:  could not bind IPv4 socket: Permission denied
HINT:  Is another postmaster already running on port 666? If not, wait a few seconds and
FATAL:  could not create TCP/IP listen socket
```

A message like:

```
FATAL:  could not create shared memory segment: Invalid argument
DETAIL:  Failed system call was shmget(key=5440001, size=4011376640, 03600).
```

probably means your kernel's limit on the size of shared memory is smaller than the work area PostgreSQL is trying to create (4011376640 bytes in this example). Or it could mean that you do not have System-V-style shared memory support configured into your kernel at all. As a temporary workaround, you can try starting the server with a smaller-than-normal number of buffers (shared_buffers). You will eventually want to reconfigure your kernel to increase the allowed shared memory size. You might also see this message when trying to start multiple servers on the same machine, if their total space requested exceeds the kernel limit.

An error like:

```
FATAL:  could not create semaphores: No space left on device
DETAIL:  Failed system call was semget(5440126, 17, 03600).
```

does *not* mean you've run out of disk space. It means your kernel's limit on the number of System V semaphores is smaller than the number PostgreSQL wants to create. As above, you might be able to work around the problem by starting the server with a reduced number of allowed connections (max_connections), but you'll eventually want to increase the kernel limit.

If you get an "illegal system call" error, it is likely that shared memory or semaphores are not supported in your kernel at all. In that case your only option is to reconfigure the kernel to enable these features.

Details about configuring System V IPC facilities are given in Section 17.4.1.

17.3.2. Client Connection Problems

Although the error conditions possible on the client side are quite varied and application-dependent, a few of them might be directly related to how the server was started. Conditions other than those shown below should be documented with the respective client application.

```
psql: could not connect to server: Connection refused
        Is the server running on host "server.joe.com" and accepting
        TCP/IP connections on port 5432?
```

This is the generic "I couldn't find a server to talk to" failure. It looks like the above when TCP/IP communication is attempted. A common mistake is to forget to configure the server to allow TCP/IP connections.

Alternatively, you'll get this when attempting Unix-domain socket communication to a local server:

```
psql: could not connect to server: No such file or directory
        Is the server running locally and accepting
        connections on Unix domain socket "/tmp/.s.PGSQL.5432"?
```

The last line is useful in verifying that the client is trying to connect to the right place. If there is in fact no server running there, the kernel error message will typically be either `Connection refused` or `No such file or directory`, as illustrated. (It is important to realize that `Connection refused` in this context does *not* mean that the server got your connection request and rejected it. That case will produce a different message, as shown in Section 19.4.) Other error messages such as `Connection timed out` might indicate more fundamental problems, like lack of network connectivity.

17.4. Managing Kernel Resources

PostgreSQL can sometimes exhaust various operating system resource limits, especially when multiple copies of the server are running on the same system, or in very large installations. This section explains the kernel resources used by PostgreSQL and the steps you can take to resolve problems related to kernel resource consumption.

17.4.1. Shared Memory and Semaphores

Shared memory and semaphores are collectively referred to as "System V IPC" (together with message queues, which are not relevant for PostgreSQL). Except on Windows, where PostgreSQL provides its own replacement implementation of these facilities, these facilities are required in order to run PostgreSQL.

The complete lack of these facilities is usually manifested by an Illegal system call error upon server start. In that case there is no alternative but to reconfigure your kernel. PostgreSQL won't work without them. This situation is rare, however, among modern operating systems.

When PostgreSQL exceeds one of the various hard IPC limits, the server will refuse to start and should leave an instructive error message describing the problem and what to do about it. (See also Section 17.3.1.) The relevant kernel parameters are named consistently across different systems; Table 17-1 gives an overview. The methods to set them, however, vary. Suggestions for some platforms are given below.

> **Note:** Prior to PostgreSQL 9.3, the amount of System V shared memory required to start the server was much larger. If you are running an older version of the server, please consult the documentation for your server version.

Table 17-1. System V IPC Parameters

Name	Description	Reasonable values
`SHMMAX`	Maximum size of shared memory segment (bytes)	at least 1kB (more if running many copies of the server)
`SHMMIN`	Minimum size of shared memory segment (bytes)	1
`SHMALL`	Total amount of shared memory available (bytes or pages)	if bytes, same as `SHMMAX`; if pages, `ceil(SHMMAX/PAGE_SIZE)`
`SHMSEG`	Maximum number of shared memory segments per process	only 1 segment is needed, but the default is much higher
`SHMMNI`	Maximum number of shared memory segments system-wide	like `SHMSEG` plus room for other applications
`SEMMNI`	Maximum number of semaphore identifiers (i.e., sets)	at least `ceil((max_connections + autovacuum_max_workers + 4) / 16)`
`SEMMNS`	Maximum number of semaphores system-wide	`ceil((max_connections + autovacuum_max_workers + 4) / 16) * 17` plus room for other applications
`SEMMSL`	Maximum number of semaphores per set	at least 17
`SEMMAP`	Number of entries in semaphore map	see text

Name	Description	Reasonable values
SEMVMX	Maximum value of semaphore	at least 1000 (The default is often 32767; do not change unless necessary)

PostgreSQL requires a few bytes of System V shared memory (typically 48 bytes, on 64-bit platforms) for each copy of the server. On most modern operating systems, this amount can easily be allocated. However, if you are running many copies of the server, or if other applications are also using System V shared memory, it may be necessary to increase SHMMAX, the maximum size in bytes of a shared memory segment, or SHMALL, the total amount of System V shared memory system-wide. Note that SHMALL is measured in pages rather than bytes on many systems.

Less likely to cause problems is the minimum size for shared memory segments (SHMMIN), which should be at most approximately 32 bytes for PostgreSQL (it is usually just 1). The maximum number of segments system-wide (SHMMNI) or per-process (SHMSEG) are unlikely to cause a problem unless your system has them set to zero.

PostgreSQL uses one semaphore per allowed connection (max_connections) and allowed autovacuum worker process (autovacuum_max_workers), in sets of 16. Each such set will also contain a 17th semaphore which contains a "magic number", to detect collision with semaphore sets used by other applications. The maximum number of semaphores in the system is set by SEMMNS, which consequently must be at least as high as max_connections plus autovacuum_max_workers, plus one extra for each 16 allowed connections plus workers (see the formula in Table 17-1). The parameter SEMMNI determines the limit on the number of semaphore sets that can exist on the system at one time. Hence this parameter must be at least ceil((max_connections + autovacuum_max_workers + 4) / 16). Lowering the number of allowed connections is a temporary workaround for failures, which are usually confusingly worded "No space left on device", from the function semget.

In some cases it might also be necessary to increase SEMMAP to be at least on the order of SEMMNS. This parameter defines the size of the semaphore resource map, in which each contiguous block of available semaphores needs an entry. When a semaphore set is freed it is either added to an existing entry that is adjacent to the freed block or it is registered under a new map entry. If the map is full, the freed semaphores get lost (until reboot). Fragmentation of the semaphore space could over time lead to fewer available semaphores than there should be.

The SEMMSL parameter, which determines how many semaphores can be in a set, must be at least 17 for PostgreSQL.

Various other settings related to "semaphore undo", such as SEMMNU and SEMUME, do not affect PostgreSQL.

AIX

At least as of version 5.1, it should not be necessary to do any special configuration for such parameters as SHMMAX, as it appears this is configured to allow all memory to be used as shared memory. That is the sort of configuration commonly used for other databases such as DB/2.

It might, however, be necessary to modify the global ulimit information in /etc/security/limits, as the default hard limits for file sizes (fsize) and numbers of files (nofiles) might be too low.

FreeBSD

The default settings can be changed using the sysctl or loader interfaces. The following parameters can be set using sysctl:

```
# sysctl kern.ipc.shmall=32768
# sysctl kern.ipc.shmmax=134217728
```

To make these settings persist over reboots, modify `/etc/sysctl.conf`.

These semaphore-related settings are read-only as far as `sysctl` is concerned, but can be set in `/boot/loader.conf`:

```
kern.ipc.semmni=256
kern.ipc.semmns=512
kern.ipc.semmnu=256
```

After modifying these values a reboot is required for the new settings to take effect. (Note: FreeBSD does not use `SEMMAP`. Older versions would accept but ignore a setting for `kern.ipc.semmap`; newer versions reject it altogether.)

You might also want to configure your kernel to lock shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

If running in FreeBSD jails by enabling sysctl's `security.jail.sysvipc_allowed`, postmasters running in different jails should be run by different operating system users. This improves security because it prevents non-root users from interfering with shared memory or semaphores in different jails, and it allows the PostgreSQL IPC cleanup code to function properly. (In FreeBSD 6.0 and later the IPC cleanup code does not properly detect processes in other jails, preventing the running of postmasters on the same port in different jails.)

FreeBSD versions before 4.0 work like OpenBSD (see below).

NetBSD

In NetBSD 5.0 and later, IPC parameters can be adjusted using `sysctl`, for example:

```
$ sysctl -w kern.ipc.shmmax=16777216
```

To have these settings persist over reboots, modify `/etc/sysctl.conf`.

You might also want to configure your kernel to lock shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

NetBSD versions before 5.0 work like OpenBSD (see below), except that parameters should be set with the keyword `options` not `option`.

OpenBSD

The options `SYSVSHM` and `SYSVSEM` need to be enabled when the kernel is compiled. (They are by default.) The maximum size of shared memory is determined by the option `SHMMAXPGS` (in pages). The following shows an example of how to set the various parameters:

```
option        SYSVSHM
option        SHMMAXPGS=4096
option        SHMSEG=256

option        SYSVSEM
option        SEMMNI=256
option        SEMMNS=512
option        SEMMNU=256
option        SEMMAP=256
```

You might also want to configure your kernel to lock shared memory into RAM and prevent it from being paged out to swap. This can be accomplished using the `sysctl` setting `kern.ipc.shm_use_phys`.

HP-UX

The default settings tend to suffice for normal installations. On HP-UX 10, the factory default for `SEMMNS` is 128, which might be too low for larger database sites.

IPC parameters can be set in the System Administration Manager (SAM) under Kernel Configuration⟶Configurable Parameters. Choose Create A New Kernel when you're done.

Linux

The default maximum segment size is 32 MB, and the default maximum total size is 2097152 pages. A page is almost always 4096 bytes except in unusual kernel configurations with "huge pages" (use `getconf PAGE_SIZE` to verify).

The shared memory size settings can be changed via the `sysctl` interface. For example, to allow 16 GB:

```
$ sysctl -w kernel.shmmax=17179869184
$ sysctl -w kernel.shmall=4194304
```

In addition these settings can be preserved between reboots in the file `/etc/sysctl.conf`. Doing that is highly recommended.

Ancient distributions might not have the `sysctl` program, but equivalent changes can be made by manipulating the `/proc` file system:

```
$ echo 17179869184 >/proc/sys/kernel/shmmax
$ echo 4194304 >/proc/sys/kernel/shmall
```

The remaining defaults are quite generously sized, and usually do not require changes.

OS X

The recommended method for configuring shared memory in OS X is to create a file named `/etc/sysctl.conf`, containing variable assignments such as:

```
kern.sysv.shmmax=4194304
kern.sysv.shmmin=1
kern.sysv.shmmni=32
kern.sysv.shmseg=8
kern.sysv.shmall=1024
```

Note that in some OS X versions, *all five* shared-memory parameters must be set in `/etc/sysctl.conf`, else the values will be ignored.

Beware that recent releases of OS X ignore attempts to set `SHMMAX` to a value that isn't an exact multiple of 4096.

`SHMALL` is measured in 4 kB pages on this platform.

In older OS X versions, you will need to reboot to have changes in the shared memory parameters take effect. As of 10.5 it is possible to change all but `SHMMNI` on the fly, using sysctl. But it's still best to set up your preferred values via `/etc/sysctl.conf`, so that the values will be kept across reboots.

The file `/etc/sysctl.conf` is only honored in OS X 10.3.9 and later. If you are running a previous 10.3.x release, you must edit the file `/etc/rc` and change the values in the following commands:

```
sysctl -w kern.sysv.shmmax
sysctl -w kern.sysv.shmmin
sysctl -w kern.sysv.shmmni
sysctl -w kern.sysv.shmseg
sysctl -w kern.sysv.shmall
```

Note that `/etc/rc` is usually overwritten by OS X system updates, so you should expect to have to redo these edits after each update.

In OS X 10.2 and earlier, instead edit these commands in the file `/System/Library/StartupItems/SystemTuning/SystemTuning`.

SCO OpenServer

In the default configuration, only 512 kB of shared memory per segment is allowed. To increase the setting, first change to the directory `/etc/conf/cf.d`. To display the current value of `SHMMAX`, run:

```
./configure -y SHMMAX
```

To set a new value for `SHMMAX`, run:

```
./configure SHMMAX=value
```

where *`value`* is the new value you want to use (in bytes). After setting `SHMMAX`, rebuild the kernel:

```
./link_unix
```

and reboot.

Solaris 2.6 to 2.9 (Solaris 6 to Solaris 9)

The relevant settings can be changed in `/etc/system`, for example:

```
set shmsys:shminfo_shmmax=0x2000000
set shmsys:shminfo_shmmin=1
set shmsys:shminfo_shmmni=256
set shmsys:shminfo_shmseg=256

set semsys:seminfo_semmap=256
set semsys:seminfo_semmni=512
set semsys:seminfo_semmns=512
set semsys:seminfo_semmsl=32
```

You need to reboot for the changes to take effect. See also http://sunsite.uakom.sk/sunworldonline/swol-09-1997/swol-09-insidesolaris.html for information on shared memory under older versions of Solaris.

Solaris 2.10 (Solaris 10) and later
OpenSolaris

In Solaris 10 and later, and OpenSolaris, the default shared memory and semaphore settings are good enough for most PostgreSQL applications. Solaris now defaults to a `SHMMAX` of one-quarter of system RAM. To further adjust this setting, use a project setting associated with the `postgres` user. For example, run the following as `root`:

```
projadd -c "PostgreSQL DB User" -K "project.max-shm-memory=(privileged,8GB,deny)" -U
```

This command adds the `user.postgres` project and sets the shared memory maximum for the `postgres` user to 8GB, and takes effect the next time that user logs in, or when you restart PostgreSQL (not reload). The above assumes that PostgreSQL is run by the `postgres` user in the `postgres` group. No server reboot is required.

Other recommended kernel setting changes for database servers which will have a large number of connections are:

```
project.max-shm-ids=(priv,32768,deny)
project.max-sem-ids=(priv,4096,deny)
project.max-msg-ids=(priv,4096,deny)
```

Additionally, if you are running PostgreSQL inside a zone, you may need to raise the zone resource usage limits as well. See "Chapter2: Projects and Tasks" in the *System Administrator's Guide* for more information on `projects` and `prctl`.

UnixWare

On UnixWare 7, the maximum size for shared memory segments is 512 kB in the default configuration. To display the current value of `SHMMAX`, run:

```
/etc/conf/bin/idtune -g SHMMAX
```

which displays the current, default, minimum, and maximum values. To set a new value for `SHMMAX`, run:

```
/etc/conf/bin/idtune SHMMAX value
```

where *value* is the new value you want to use (in bytes). After setting `SHMMAX`, rebuild the kernel:

```
/etc/conf/bin/idbuild -B
```

and reboot.

17.4.2. Resource Limits

Unix-like operating systems enforce various kinds of resource limits that might interfere with the operation of your PostgreSQL server. Of particular importance are limits on the number of processes per user, the number of open files per process, and the amount of memory available to each process. Each of these have a "hard" and a "soft" limit. The soft limit is what actually counts but it can be changed by the user up to the hard limit. The hard limit can only be changed by the root user. The system call `setrlimit` is responsible for setting these parameters. The shell's built-in command `ulimit` (Bourne shells) or `limit` (csh) is used to control the resource limits from the command line. On BSD-derived systems the file `/etc/login.conf` controls the various resource limits set during login. See the operating system documentation for details. The relevant parameters are `maxproc`, `openfiles`, and `datasize`. For example:

```
default:\
...
        :datasize-cur=256M:\
        :maxproc-cur=256:\
        :openfiles-cur=256:\
...
```

(`-cur` is the soft limit. Append `-max` to set the hard limit.)

Kernels can also have system-wide limits on some resources.

- On Linux `/proc/sys/fs/file-max` determines the maximum number of open files that the kernel will support. It can be changed by writing a different number into the file or by adding an assignment in `/etc/sysctl.conf`. The maximum limit of files per process is fixed at the time the kernel is compiled; see `/usr/src/linux/Documentation/proc.txt` for more information.

The PostgreSQL server uses one process per connection so you should provide for at least as many processes as allowed connections, in addition to what you need for the rest of your system. This is usually not a problem but if you run several servers on one machine things might get tight.

The factory default limit on open files is often set to "socially friendly" values that allow many users to coexist on a machine without using an inappropriate fraction of the system resources. If you run many servers on a machine this is perhaps what you want, but on dedicated servers you might want to raise this limit.

On the other side of the coin, some systems allow individual processes to open large numbers of files; if more than a few processes do so then the system-wide limit can easily be exceeded. If you find this happening, and you do not want to alter the system-wide limit, you can set PostgreSQL's max_files_per_process configuration parameter to limit the consumption of open files.

17.4.3. Linux Memory Overcommit

In Linux 2.4 and later, the default virtual memory behavior is not optimal for PostgreSQL. Because of the way that the kernel implements memory overcommit, the kernel might terminate the PostgreSQL postmaster (the master server process) if the memory demands of either PostgreSQL or another process cause the system to run out of virtual memory.

If this happens, you will see a kernel message that looks like this (consult your system documentation and configuration on where to look for such a message):

```
Out of Memory: Killed process 12345 (postgres).
```

This indicates that the `postgres` process has been terminated due to memory pressure. Although existing database connections will continue to function normally, no new connections will be accepted. To recover, PostgreSQL will need to be restarted.

One way to avoid this problem is to run PostgreSQL on a machine where you can be sure that other processes will not run the machine out of memory. If memory is tight, increasing the swap space of the operating system can help avoid the problem, because the out-of-memory (OOM) killer is invoked only when physical memory and swap space are exhausted.

If PostgreSQL itself is the cause of the system running out of memory, you can avoid the problem by changing your configuration. In some cases, it may help to lower memory-related configuration parameters, particularly `shared_buffers` and `work_mem`. In other cases, the problem may be caused by allowing too many connections to the database server itself. In many cases, it may be better to reduce `max_connections` and instead make use of external connection-pooling software.

On Linux 2.6 and later, it is possible to modify the kernel's behavior so that it will not "overcommit" memory. Although this setting will not prevent the OOM killer[1] from being invoked altogether, it will lower the chances significantly and will therefore lead to more robust system behavior. This is done by selecting strict overcommit mode via `sysctl`:

```
sysctl -w vm.overcommit_memory=2
```

or placing an equivalent entry in `/etc/sysctl.conf`. You might also wish to modify the related setting `vm.overcommit_ratio`. For details see the kernel documentation file `Documentation/vm/overcommit-accounting`.

Another approach, which can be used with or without altering `vm.overcommit_memory`, is to set the process-specific `oom_score_adj` value for the postmaster process to `-1000`, thereby guaranteeing it will not be targeted by the OOM killer. The simplest way to do this is to execute

```
echo -1000 > /proc/self/oom_score_adj
```

in the postmaster's startup script just before invoking the postmaster. Note that this action must be done as root, or it will have no effect; so a root-owned startup script is the easiest place to do it. If you do this, you may also wish to build PostgreSQL with `-DLINUX_OOM_SCORE_ADJ=0` added to `CPPFLAGS`. That will cause postmaster child processes to run with the normal `oom_score_adj` value of zero, so that the OOM killer can still target them at need.

1. http://lwn.net/Articles/104179/

Older Linux kernels do not offer /proc/self/oom_score_adj, but may have a previous version of the same functionality called /proc/self/oom_adj. This works the same except the disable value is -17 not -1000. The corresponding build flag for PostgreSQL is -DLINUX_OOM_ADJ=0.

> **Note:** Some vendors' Linux 2.4 kernels are reported to have early versions of the 2.6 overcommit sysctl parameter. However, setting vm.overcommit_memory to 2 on a 2.4 kernel that does not have the relevant code will make things worse, not better. It is recommended that you inspect the actual kernel source code (see the function vm_enough_memory in the file mm/mmap.c) to verify what is supported in your kernel before you try this in a 2.4 installation. The presence of the overcommit-accounting documentation file should *not* be taken as evidence that the feature is there. If in any doubt, consult a kernel expert or your kernel vendor.

17.4.4. Linux huge pages

Using huge pages reduces overhead when using large contiguous chunks of memory, like PostgreSQL does. To enable this feature in PostgreSQL you need a kernel with CONFIG_HUGETLBFS=y and CONFIG_HUGETLB_PAGE=y. You also have to tune the system setting vm.nr_hugepages. To estimate the number of necessary huge pages start PostgreSQL without huge pages enabled and check the VmPeak value from the proc file system:

```
$ head -1 /path/to/data/directory/postmaster.pid
4170
$ grep ^VmPeak /proc/4170/status
VmPeak:  6490428 kB
```

6490428 / 2048 (PAGE_SIZE is 2MB in this case) are roughly 3169.154 huge pages, so you will need at least 3170 huge pages:

```
$ sysctl -w vm.nr_hugepages=3170
```

Sometimes the kernel is not able to allocate the desired number of huge pages, so it might be necessary to repeat that command or to reboot. Don't forget to add an entry to /etc/sysctl.conf to persist this setting through reboots.

The default behavior for huge pages in PostgreSQL is to use them when possible and to fallback to normal pages when failing. To enforce the use of huge pages, you can set huge_pages to on. Note that in this case PostgreSQL will fail to start if not enough huge pages are available.

For a detailed description of the Linux huge pages feature have a look at https://www.kernel.org/doc/Documentation/vm/hugetlbpage.txt.

17.5. Shutting Down the Server

There are several ways to shut down the database server. You control the type of shutdown by sending different signals to the master postgres process.

SIGTERM

This is the *Smart Shutdown* mode. After receiving SIGTERM, the server disallows new connections, but lets existing sessions end their work normally. It shuts down only after all of the ses-

sions terminate. If the server is in online backup mode, it additionally waits until online backup mode is no longer active. While backup mode is active, new connections will still be allowed, but only to superusers (this exception allows a superuser to connect to terminate online backup mode). If the server is in recovery when a smart shutdown is requested, recovery and streaming replication will be stopped only after all regular sessions have terminated.

SIGINT

This is the *Fast Shutdown* mode. The server disallows new connections and sends all existing server processes SIGTERM, which will cause them to abort their current transactions and exit promptly. It then waits for all server processes to exit and finally shuts down. If the server is in online backup mode, backup mode will be terminated, rendering the backup useless.

SIGQUIT

This is the *Immediate Shutdown* mode. The server will send SIGQUIT to all child processes and wait for them to terminate. Those that don't terminate within 5 seconds, will be sent SIGKILL by the master `postgres` process, which will then terminate without further waiting. This will lead to recovery (by replaying the WAL log) upon next start-up. This is recommended only in emergencies.

The pg_ctl program provides a convenient interface for sending these signals to shut down the server. Alternatively, you can send the signal directly using `kill` on non-Windows systems. The PID of the `postgres` process can be found using the `ps` program, or from the file `postmaster.pid` in the data directory. For example, to do a fast shutdown:

```
$ kill -INT `head -1 /usr/local/pgsql/data/postmaster.pid`
```

Important: It is best not to use SIGKILL to shut down the server. Doing so will prevent the server from releasing shared memory and semaphores, which might then have to be done manually before a new server can be started. Furthermore, SIGKILL kills the `postgres` process without letting it relay the signal to its subprocesses, so it will be necessary to kill the individual subprocesses by hand as well.

To terminate an individual session while allowing other sessions to continue, use `pg_terminate_backend()` (see Table 9-64) or send a SIGTERM signal to the child process associated with the session.

17.6. Upgrading a PostgreSQL Cluster

This section discusses how to upgrade your database data from one PostgreSQL release to a newer one.

PostgreSQL major versions are represented by the first two digit groups of the version number, e.g., 8.4. PostgreSQL minor versions are represented by the third group of version digits, e.g., 8.4.2 is the second minor release of 8.4. Minor releases never change the internal storage format and are always compatible with earlier and later minor releases of the same major version number, e.g., 8.4.2 is compatible with 8.4, 8.4.1 and 8.4.6. To update between compatible versions, you simply replace the executables while the server is down and restart the server. The data directory remains unchanged — minor upgrades are that simple.

For *major* releases of PostgreSQL, the internal data storage format is subject to change, thus complicating upgrades. The traditional method for moving data to a new major version is to dump and reload the database, though this can be slow. A faster method is pg_upgrade. Replication methods are also available, as discussed below.

New major versions also typically introduce some user-visible incompatibilities, so application programming changes might be required. All user-visible changes are listed in the release notes (Appendix E); pay particular attention to the section labeled "Migration". If you are upgrading across several major versions, be sure to read the release notes for each intervening version.

Cautious users will want to test their client applications on the new version before switching over fully; therefore, it's often a good idea to set up concurrent installations of old and new versions. When testing a PostgreSQL major upgrade, consider the following categories of possible changes:

Administration

: The capabilities available for administrators to monitor and control the server often change and improve in each major release.

SQL

: Typically this includes new SQL command capabilities and not changes in behavior, unless specifically mentioned in the release notes.

Library API

: Typically libraries like libpq only add new functionality, again unless mentioned in the release notes.

System Catalogs

: System catalog changes usually only affect database management tools.

Server C-language API

: This involves changes in the backend function API, which is written in the C programming language. Such changes affect code that references backend functions deep inside the server.

17.6.1. Upgrading Data via pg_dumpall

One upgrade method is to dump data from one major version of PostgreSQL and reload it in another — to do this, you must use a *logical* backup tool like pg_dumpall; file system level backup methods will not work. (There are checks in place that prevent you from using a data directory with an incompatible version of PostgreSQL, so no great harm can be done by trying to start the wrong server version on a data directory.)

It is recommended that you use the pg_dump and pg_dumpall programs from the *newer* version of PostgreSQL, to take advantage of enhancements that might have been made in these programs. Current releases of the dump programs can read data from any server version back to 7.0.

These instructions assume that your existing installation is under the `/usr/local/pgsql` directory, and that the data area is in `/usr/local/pgsql/data`. Substitute your paths appropriately.

1. If making a backup, make sure that your database is not being updated. This does not affect the integrity of the backup, but the changed data would of course not be included. If necessary, edit the permissions in the file `/usr/local/pgsql/data/pg_hba.conf` (or equivalent) to disallow access from everyone except you. See Chapter 19 for additional information on access control.

   To back up your database installation, type:

pg_dumpall > *outputfile*

To make the backup, you can use the pg_dumpall command from the version you are currently running; see Section 24.1.2 for more details. For best results, however, try to use the pg_dumpall command from PostgreSQL 9.4.1, since this version contains bug fixes and improvements over older versions. While this advice might seem idiosyncratic since you haven't installed the new version yet, it is advisable to follow it if you plan to install the new version in parallel with the old version. In that case you can complete the installation normally and transfer the data later. This will also decrease the downtime.

2. Shut down the old server:

   pg_ctl stop
   On systems that have PostgreSQL started at boot time, there is probably a start-up file that will accomplish the same thing. For example, on a Red Hat Linux system one might find that this works:

   /etc/rc.d/init.d/postgresql stop
   See Chapter 17 for details about starting and stopping the server.

3. If restoring from backup, rename or delete the old installation directory if it is not version-specific. It is a good idea to rename the directory, rather than delete it, in case you have trouble and need to revert to it. Keep in mind the directory might consume significant disk space. To rename the directory, use a command like this:

   mv /usr/local/pgsql /usr/local/pgsql.old
   (Be sure to move the directory as a single unit so relative paths remain unchanged.)

4. Install the new version of PostgreSQL as outlined in Section 15.4.

5. Create a new database cluster if needed. Remember that you must execute these commands while logged in to the special database user account (which you already have if you are upgrading).

   /usr/local/pgsql/bin/initdb -D /usr/local/pgsql/data

6. Restore your previous `pg_hba.conf` and any `postgresql.conf` modifications.

7. Start the database server, again using the special database user account:

   /usr/local/pgsql/bin/postgres -D /usr/local/pgsql/data

8. Finally, restore your data from backup with:

   /usr/local/pgsql/bin/psql -d postgres -f *outputfile*
   using the *new* psql.

The least downtime can be achieved by installing the new server in a different directory and running both the old and the new servers in parallel, on different ports. Then you can use something like:

```
pg_dumpall -p 5432 | psql -d postgres -p 5433
```

to transfer your data.

17.6.2. Upgrading Data via pg_upgrade

The pg_upgrade module allows an installation to be migrated in-place from one major PostgreSQL version to another. Upgrades can be performed in minutes, particularly with `--link` mode. It requires steps similar to pg_dumpall above, e.g. starting/stopping the server, running initdb. The pg_upgrade documentation outlines the necessary steps.

17.6.3. Upgrading Data via Replication

It is also possible to use certain replication methods, such as Slony, to create a standby server with the updated version of PostgreSQL. This is possible because Slony supports replication between different major versions of PostgreSQL. The standby can be on the same computer or a different computer. Once it has synced up with the master server (running the older version of PostgreSQL), you can switch masters and make the standby the master and shut down the older database instance. Such a switch-over results in only several seconds of downtime for an upgrade.

17.7. Preventing Server Spoofing

While the server is running, it is not possible for a malicious user to take the place of the normal database server. However, when the server is down, it is possible for a local user to spoof the normal server by starting their own server. The spoof server could read passwords and queries sent by clients, but could not return any data because the `PGDATA` directory would still be secure because of directory permissions. Spoofing is possible because any user can start a database server; a client cannot identify an invalid server unless it is specially configured.

The simplest way to prevent spoofing for `local` connections is to use a Unix domain socket directory (unix_socket_directories) that has write permission only for a trusted local user. This prevents a malicious user from creating their own socket file in that directory. If you are concerned that some applications might still reference `/tmp` for the socket file and hence be vulnerable to spoofing, during operating system startup create a symbolic link `/tmp/.s.PGSQL.5432` that points to the relocated socket file. You also might need to modify your `/tmp` cleanup script to prevent removal of the symbolic link.

To prevent spoofing on TCP connections, the best solution is to use SSL certificates and make sure that clients check the server's certificate. To do that, the server must be configured to accept only `hostssl` connections (Section 19.1) and have SSL key and certificate files (Section 17.9). The TCP client must connect using `sslmode=verify-ca` or `verify-full` and have the appropriate root certificate file installed (Section 31.18.1).

17.8. Encryption Options

PostgreSQL offers encryption at several levels, and provides flexibility in protecting data from disclosure due to database server theft, unscrupulous administrators, and insecure networks. Encryption might also be required to secure sensitive data such as medical records or financial transactions.

Password Storage Encryption

By default, database user passwords are stored as MD5 hashes, so the administrator cannot determine the actual password assigned to the user. If MD5 encryption is used for client authentication, the unencrypted password is never even temporarily present on the server because the client MD5-encrypts it before being sent across the network.

Encryption For Specific Columns

The pgcrypto module allows certain fields to be stored encrypted. This is useful if only some of the data is sensitive. The client supplies the decryption key and the data is decrypted on the server and then sent to the client.

The decrypted data and the decryption key are present on the server for a brief time while it is being decrypted and communicated between the client and server. This presents a brief moment where the data and keys can be intercepted by someone with complete access to the database server, such as the system administrator.

Data Partition Encryption

Storage encryption can be performed at the file system level or the block level. Linux file system encryption options include eCryptfs and EncFS, while FreeBSD uses PEFS. Block level or full disk encryption options include dm-crypt + LUKS on Linux and GEOM modules geli and gbde on FreeBSD. Many other operating systems support this functionality, including Windows.

This mechanism prevents unencrypted data from being read from the drives if the drives or the entire computer is stolen. This does not protect against attacks while the file system is mounted, because when mounted, the operating system provides an unencrypted view of the data. However, to mount the file system, you need some way for the encryption key to be passed to the operating system, and sometimes the key is stored somewhere on the host that mounts the disk.

Encrypting Passwords Across A Network

The `MD5` authentication method double-encrypts the password on the client before sending it to the server. It first MD5-encrypts it based on the user name, and then encrypts it based on a random salt sent by the server when the database connection was made. It is this double-encrypted value that is sent over the network to the server. Double-encryption not only prevents the password from being discovered, it also prevents another connection from using the same encrypted password to connect to the database server at a later time.

Encrypting Data Across A Network

SSL connections encrypt all data sent across the network: the password, the queries, and the data returned. The `pg_hba.conf` file allows administrators to specify which hosts can use non-encrypted connections (`host`) and which require SSL-encrypted connections (`hostssl`). Also, clients can specify that they connect to servers only via SSL. Stunnel or SSH can also be used to encrypt transmissions.

SSL Host Authentication

It is possible for both the client and server to provide SSL certificates to each other. It takes some extra configuration on each side, but this provides stronger verification of identity than the mere use of passwords. It prevents a computer from pretending to be the server just long enough to read the password sent by the client. It also helps prevent “man in the middle” attacks where a computer between the client and server pretends to be the server and reads and passes all data between the client and server.

Client-Side Encryption

If the system administrator for the server’s machine cannot be trusted, it is necessary for the client to encrypt the data; this way, unencrypted data never appears on the database server. Data is encrypted on the client before being sent to the server, and database results have to be decrypted on the client before being used.

17.9. Secure TCP/IP Connections with SSL

PostgreSQL has native support for using SSL connections to encrypt client/server communications for increased security. This requires that OpenSSL is installed on both client and server systems and that support in PostgreSQL is enabled at build time (see Chapter 15).

With SSL support compiled in, the PostgreSQL server can be started with SSL enabled by setting the parameter ssl to `on` in `postgresql.conf`. The server will listen for both normal and SSL connections on the same TCP port, and will negotiate with any connecting client on whether to use SSL. By default, this is at the client's option; see Section 19.1 about how to set up the server to require use of SSL for some or all connections.

PostgreSQL reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

OpenSSL supports a wide range of ciphers and authentication algorithms, of varying strength. While a list of ciphers can be specified in the OpenSSL configuration file, you can specify ciphers specifically for use by the database server by modifying ssl_ciphers in `postgresql.conf`.

> **Note:** It is possible to have authentication without encryption overhead by using `NULL-SHA` or `NULL-MD5` ciphers. However, a man-in-the-middle could read and pass communications between client and server. Also, encryption overhead is minimal compared to the overhead of authentication. For these reasons NULL ciphers are not recommended.

To start in SSL mode, files containing the server certificate and private key must exist. By default, these files are expected to be named `server.crt` and `server.key`, respectively, in the server's data directory, but other names and locations can be specified using the configuration parameters ssl_cert_file and ssl_key_file. On Unix systems, the permissions on `server.key` must disallow any access to world or group; achieve this by the command `chmod 0600 server.key`. If the private key is protected with a passphrase, the server will prompt for the passphrase and will not start until it has been entered.

In some cases, the server certificate might be signed by an "intermediate" certificate authority, rather than one that is directly trusted by clients. To use such a certificate, append the certificate of the signing authority to the `server.crt` file, then its parent authority's certificate, and so on up to a certificate authority, "root" or "intermediate", that is trusted by clients, i.e. signed by a certificate in the clients' `root.crt` files.

17.9.1. Using Client Certificates

To require the client to supply a trusted certificate, place certificates of the certificate authorities (CAs) you trust in the file `root.crt` in the data directory, set the parameter ssl_ca_file in `postgresql.conf` to `root.crt`, and set the `clientcert` parameter to 1 on the appropriate `hostssl` line(s) in `pg_hba.conf`. A certificate will then be requested from the client during SSL connection startup. (See Section 31.18 for a description of how to set up certificates on the client.) The server will verify that the client's certificate is signed by one of the trusted certificate authorities. If intermediate CAs appear in `root.crt`, the file must also contain certificate chains to their root CAs. Certificate Revocation List (CRL) entries are also checked if the parameter ssl_crl_file is set. (See http://h71000.www7.hp.com/DOC/83final/BA554_90007/ch04s02.html for diagrams showing SSL certificate usage.)

The `clientcert` option in `pg_hba.conf` is available for all authentication methods, but only for rows specified as `hostssl`. When `clientcert` is not specified or is set to 0, the server will still verify presented client certificates against its CA list, if one is configured, — but it will not insist that a client certificate be presented.

Note that the server's `root.crt` lists the top-level CAs that are considered trusted for signing client certificates. In principle it need not list the CA that signed the server's certificate, though in most cases that CA would also be trusted for client certificates.

If you are setting up client certificates, you may wish to use the `cert` authentication method, so that the certificates control user authentication as well as providing connection security. See Section 19.3.9 for details.

17.9.2. SSL Server File Usage

Table 17-2 summarizes the files that are relevant to the SSL setup on the server. (The shown file names are default or typical names. The locally configured names could be different.)

Table 17-2. SSL Server File Usage

File	Contents	Effect
ssl_cert_file (`$PGDATA/server.crt`)	server certificate	sent to client to indicate server's identity
ssl_key_file (`$PGDATA/server.key`)	server private key	proves server certificate was sent by the owner; does not indicate certificate owner is trustworthy
ssl_ca_file (`$PGDATA/root.crt`)	trusted certificate authorities	checks that client certificate is signed by a trusted certificate authority
ssl_crl_file (`$PGDATA/root.crl`)	certificates revoked by certificate authorities	client certificate must not be on this list

The files `server.key`, `server.crt`, `root.crt`, and `root.crl` (or their configured alternative names) are only examined during server start; so you must restart the server for changes in them to take effect.

17.9.3. Creating a Self-signed Certificate

To create a quick self-signed certificate for the server, use the following OpenSSL command:

```
openssl req -new -text -out server.req
```

Fill out the information that openssl asks for. Make sure you enter the local host name as "Common Name"; the challenge password can be left blank. The program will generate a key that is passphrase protected; it will not accept a passphrase that is less than four characters long. To remove the passphrase (as you must if you want automatic start-up of the server), run the commands:

```
openssl rsa -in privkey.pem -out server.key
rm privkey.pem
```

Enter the old passphrase to unlock the existing key. Now do:

```
openssl req -x509 -in server.req -text -key server.key -out server.crt
```

to turn the certificate into a self-signed certificate and to copy the key and certificate to where the server will look for them. Finally do:

```
chmod og-rwx server.key
```

because the server will reject the file if its permissions are more liberal than this. For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) (either one of the global CAs or a local one) should be used in production so that clients can verify the server's identity. If all the clients are local to the organization, using a local CA is recommended.

17.10. Secure TCP/IP Connections with SSH Tunnels

It is possible to use SSH to encrypt the network connection between clients and a PostgreSQL server. Done properly, this provides an adequately secure network connection, even for non-SSL-capable clients.

First make sure that an SSH server is running properly on the same machine as the PostgreSQL server and that you can log in using `ssh` as some user. Then you can establish a secure tunnel with a command like this from the client machine:

```
ssh -L 63333:localhost:5432 joe@foo.com
```

The first number in the `-L` argument, 63333, is the port number of your end of the tunnel; it can be any unused port. (IANA reserves ports 49152 through 65535 for private use.) The second number, 5432, is the remote end of the tunnel: the port number your server is using. The name or IP address between the port numbers is the host with the database server you are going to connect to, as seen from the host you are logging in to, which is `foo.com` in this example. In order to connect to the database server using this tunnel, you connect to port 63333 on the local machine:

```
psql -h localhost -p 63333 postgres
```

To the database server it will then look as though you are really user `joe` on host `foo.com` connecting to `localhost` in that context, and it will use whatever authentication procedure was configured for connections from this user and host. Note that the server will not think the connection is SSL-encrypted, since in fact it is not encrypted between the SSH server and the PostgreSQL server. This should not pose any extra security risk as long as they are on the same machine.

In order for the tunnel setup to succeed you must be allowed to connect via `ssh` as `joe@foo.com`, just as if you had attempted to use `ssh` to create a terminal session.

You could also have set up the port forwarding as

```
ssh -L 63333:foo.com:5432 joe@foo.com
```

but then the database server will see the connection as coming in on its `foo.com` interface, which is not opened by the default setting `listen_addresses = 'localhost'`. This is usually not what you want.

If you have to "hop" to the database server via some login host, one possible setup could look like this:

```
ssh -L 63333:db.foo.com:5432 joe@shell.foo.com
```

Note that this way the connection from `shell.foo.com` to `db.foo.com` will not be encrypted by the SSH tunnel. SSH offers quite a few configuration possibilities when the network is restricted in various ways. Please refer to the SSH documentation for details.

> **Tip:** Several other applications exist that can provide secure tunnels using a procedure similar in concept to the one just described.

17.11. Registering Event Log on Windows

To register a Windows event log library with the operating system, issue this command:

```
regsvr32 pgsql_library_directory/pgevent.dll
```

This creates registry entries used by the event viewer, under the default event source named `PostgreSQL`.

To specify a different event source name (see event_source), use the `/n` and `/i` options:

```
regsvr32 /n /i:event_source_name pgsql_library_directory/pgevent.dll
```

To unregister the event log library from the operating system, issue this command:

```
regsvr32 /u [/i:event_source_name] pgsql_library_directory/pgevent.dll
```

> **Note:** To enable event logging in the database server, modify log_destination to include `eventlog` in `postgresql.conf`.

Chapter 18. Server Configuration

There are many configuration parameters that affect the behavior of the database system. In the first section of this chapter we describe how to interact with configuration parameters. The subsequent sections discuss each parameter in detail.

18.1. Setting Parameters

18.1.1. Parameter Names and Values

All parameter names are case-insensitive. Every parameter takes a value of one of five types: boolean, string, integer, floating point, or enumerated (enum). The type determines the syntax for setting the parameter:

- *Boolean:* Values can be written as `on`, `off`, `true`, `false`, `yes`, `no`, `1`, `0` (all case-insensitive) or any unambiguous prefix of one of these.
- *String:* In general, enclose the value in single quotes, doubling any single quotes within the value. Quotes can usually be omitted if the value is a simple number or identifier, however.
- *Numeric (integer and floating point):* A decimal point is permitted only for floating-point parameters. Do not use thousands separators. Quotes are not required.
- *Numeric with Unit:* Some numeric parameters have an implicit unit, because they describe quantities of memory or time. The unit might be kilobytes, blocks (typically eight kilobytes), milliseconds, seconds, or minutes. An unadorned numeric value for one of these settings will use the setting's default unit, which can be learned from `pg_settings.unit`. For convenience, settings can be given with a unit specified explicitly, for example `'120 ms'` for a time value, and they will be converted to whatever the parameter's actual unit is. Note that the value must be written as a string (with quotes) to use this feature. The unit name is case-sensitive, and there can be whitespace between the numeric value and the unit.
  - Valid memory units are `kB` (kilobytes), `MB` (megabytes), `GB` (gigabytes), and `TB` (terabytes). The multiplier for memory units is 1024, not 1000.
  - Valid time units are `ms` (milliseconds), `s` (seconds), `min` (minutes), `h` (hours), and `d` (days).
- *Enumerated:* Enumerated-type parameters are written in the same way as string parameters, but are restricted to have one of a limited set of values. The values allowable for such a parameter can be found from `pg_settings.enumvals`. Enum parameter values are case-insensitive.

18.1.2. Parameter Interaction via the Configuration File

The most fundamental way to set these parameters is to edit the file `postgresql.conf`, which is normally kept in the data directory. A default copy is installed when the database cluster directory is initialized. An example of what this file might look like is:

```
# This is a comment
log_connections = yes
log_destination = 'syslog'
search_path = '"$user", public'
shared_buffers = 128MB
```

One parameter is specified per line. The equal sign between name and value is optional. Whitespace is insignificant (except within a quoted parameter value) and blank lines are ignored. Hash marks (#) designate the remainder of the line as a comment. Parameter values that are not simple identifiers or numbers must be single-quoted. To embed a single quote in a parameter value, write either two quotes (preferred) or backslash-quote.

Parameters set in this way provide default values for the cluster. The settings seen by active sessions will be these values unless they are overridden. The following sections describe ways in which the administrator or user can override these defaults.

The configuration file is reread whenever the main server process receives a SIGHUP signal; this signal is most easily sent by running `pg_ctl reload` from the command line or by calling the SQL function `pg_reload_conf()`. The main server process also propagates this signal to all currently running server processes, so that existing sessions also adopt the new values (this will happen after they complete any currently-executing client command). Alternatively, you can send the signal to a single server process directly. Some parameters can only be set at server start; any changes to their entries in the configuration file will be ignored until the server is restarted. Invalid parameter settings in the configuration file are likewise ignored (but logged) during SIGHUP processing.

In addition to `postgresql.conf`, a PostgreSQL data directory contains a file `postgresql.auto.conf`, which has the same format as `postgresql.conf` but should never be edited manually. This file holds settings provided through the ALTER SYSTEM command. This file is automatically read whenever `postgresql.conf` is, and its settings take effect in the same way. Settings in `postgresql.auto.conf` override those in `postgresql.conf`.

18.1.3. Parameter Interaction via SQL

PostgreSQL provides three SQL commands to establish configuration defaults. The already-mentioned ALTER SYSTEM command provides a SQL-accessible means of changing global defaults; it is functionally equivalent to editing `postgresql.conf`. In addition, there are two commands that allow setting of defaults on a per-database or per-role basis:

- The ALTER DATABASE command allows global settings to be overridden on a per-database basis.
- The ALTER ROLE command allows both global and per-database settings to be overridden with user-specific values.

Values set with `ALTER DATABASE` and `ALTER ROLE` are applied only when starting a fresh database session. They override values obtained from the configuration files or server command line, and constitute defaults for the rest of the session. Note that some settings cannot be changed after server start, and so cannot be set with these commands (or the ones listed below).

Once a client is connected to the database, PostgreSQL provides two additional SQL commands (and equivalent functions) to interact with session-local configuration settings:

- The SHOW command allows inspection of the current value of all parameters. The corresponding function is `current_setting(setting_name text)`.
- The SET command allows modification of the current value of those parameters that can be set locally to a session; it has no effect on other sessions. The corresponding function is `set_config(setting_name, new_value, is_local)`.

In addition, the system view `pg_settings` can be used to view and change session-local values:

- Querying this view is similar to using `SHOW ALL` but provides more detail. It is also more flexible, since it's possible to specify filter conditions or join against other relations.
- Using UPDATE on this view, specifically updating the `setting` column, is the equivalent of issuing `SET` commands. For example, the equivalent of

  ```
  SET configuration_parameter TO DEFAULT;
  ```
  is:

  ```
  UPDATE pg_settings SET setting = reset_val WHERE name = 'configuration_parameter';
  ```

18.1.4. Parameter Interaction via the Shell

In addition to setting global defaults or attaching overrides at the database or role level, you can pass settings to PostgreSQL via shell facilities. Both the server and libpq client library accept parameter values via the shell.

- During server startup, parameter settings can be passed to the `postgres` command via the `-c` command-line parameter. For example,

  ```
  postgres -c log_connections=yes -c log_destination='syslog'
  ```
  Settings provided in this way override those set via `postgresql.conf` or `ALTER SYSTEM`, so they cannot be changed globally without restarting the server.
- When starting a client session via libpq, parameter settings can be specified using the `PGOPTIONS` environment variable. Settings established in this way constitute defaults for the life of the session, but do not affect other sessions. For historical reasons, the format of `PGOPTIONS` is similar to that used when launching the `postgres` command; specifically, the `-c` flag must be specified. For example,

  ```
  env PGOPTIONS="-c geqo=off -c statement_timeout=5min" psql
  ```

  Other clients and libraries might provide their own mechanisms, via the shell or otherwise, that allow the user to alter session settings without direct use of SQL commands.

18.1.5. Managing Configuration File Contents

PostgreSQL provides several features for breaking down complex `postgresql.conf` files into sub-files. These features are especially useful when managing multiple servers with related, but not identical, configurations.

In addition to individual parameter settings, the `postgresql.conf` file can contain *include directives*, which specify another file to read and process as if it were inserted into the configuration file at this point. This feature allows a configuration file to be divided into physically separate parts. Include directives simply look like:

```
include 'filename'
```

If the file name is not an absolute path, it is taken as relative to the directory containing the referencing configuration file. Inclusions can be nested.

There is also an `include_if_exists` directive, which acts the same as the `include` directive, except when the referenced file does not exist or cannot be read. A regular `include` will consider this an error condition, but `include_if_exists` merely logs a message and continues processing the referencing configuration file.

The postgresql.conf file can also contain include_dir directives, which specify an entire directory of configuration files to include. These look like

```
include_dir 'directory'
```

Non-absolute directory names are taken as relative to the directory containing the referencing configuration file. Within the specified directory, only non-directory files whose names end with the suffix .conf will be included. File names that start with the . character are also ignored, to prevent mistakes since such files are hidden on some platforms. Multiple files within an include directory are processed in file name order (according to C locale rules, i.e. numbers before letters, and uppercase letters before lowercase ones).

Include files or directories can be used to logically separate portions of the database configuration, rather than having a single large postgresql.conf file. Consider a company that has two database servers, each with a different amount of memory. There are likely elements of the configuration both will share, for things such as logging. But memory-related parameters on the server will vary between the two. And there might be server specific customizations, too. One way to manage this situation is to break the custom configuration changes for your site into three files. You could add this to the end of your postgresql.conf file to include them:

```
include 'shared.conf'
include 'memory.conf'
include 'server.conf'
```

All systems would have the same shared.conf. Each server with a particular amount of memory could share the same memory.conf; you might have one for all servers with 8GB of RAM, another for those having 16GB. And finally server.conf could have truly server-specific configuration information in it.

Another possibility is to create a configuration file directory and put this information into files there. For example, a conf.d directory could be referenced at the end of postgresql.conf:

```
include_dir 'conf.d'
```

Then you could name the files in the conf.d directory like this:

```
00shared.conf
01memory.conf
02server.conf
```

This naming convention establishes a clear order in which these files will be loaded. This is important because only the last setting encountered for a particular parameter while the server is reading configuration files will be used. In this example, something set in conf.d/02server.conf would override a value set in conf.d/01memory.conf.

You might instead use this approach to naming the files descriptively:

```
00shared.conf
01memory-8GB.conf
02server-foo.conf
```

This sort of arrangement gives a unique name for each configuration file variation. This can help eliminate ambiguity when several servers have their configurations all stored in one place, such as in a version control repository. (Storing database configuration files under version control is another good practice to consider.)

18.2. File Locations

In addition to the postgresql.conf file already mentioned, PostgreSQL uses two other manually-edited configuration files, which control client authentication (their use is discussed in Chapter 19). By default, all three configuration files are stored in the database cluster's data directory. The parameters described in this section allow the configuration files to be placed elsewhere. (Doing so can ease administration. In particular it is often easier to ensure that the configuration files are properly backed-up when they are kept separate.)

data_directory (string)

Specifies the directory to use for data storage. This parameter can only be set at server start.

config_file (string)

Specifies the main server configuration file (customarily called postgresql.conf). This parameter can only be set on the postgres command line.

hba_file (string)

Specifies the configuration file for host-based authentication (customarily called pg_hba.conf). This parameter can only be set at server start.

ident_file (string)

Specifies the configuration file for Section 19.2 user name mapping (customarily called pg_ident.conf). This parameter can only be set at server start.

external_pid_file (string)

Specifies the name of an additional process-ID (PID) file that the server should create for use by server administration programs. This parameter can only be set at server start.

In a default installation, none of the above parameters are set explicitly. Instead, the data directory is specified by the -D command-line option or the PGDATA environment variable, and the configuration files are all found within the data directory.

If you wish to keep the configuration files elsewhere than the data directory, the postgres -D command-line option or PGDATA environment variable must point to the directory containing the configuration files, and the data_directory parameter must be set in postgresql.conf (or on the command line) to show where the data directory is actually located. Notice that data_directory overrides -D and PGDATA for the location of the data directory, but not for the location of the configuration files.

If you wish, you can specify the configuration file names and locations individually using the parameters config_file, hba_file and/or ident_file. config_file can only be specified on the postgres command line, but the others can be set within the main configuration file. If all three parameters plus data_directory are explicitly set, then it is not necessary to specify -D or PGDATA.

When setting any of these parameters, a relative path will be interpreted with respect to the directory in which postgres is started.

18.3. Connections and Authentication

18.3.1. Connection Settings

`listen_addresses` (`string`)

Specifies the TCP/IP address(es) on which the server is to listen for connections from client applications. The value takes the form of a comma-separated list of host names and/or numeric IP addresses. The special entry `*` corresponds to all available IP interfaces. The entry `0.0.0.0` allows listening for all IPv4 addresses and `::` allows listening for all IPv6 addresses. If the list is empty, the server does not listen on any IP interface at all, in which case only Unix-domain sockets can be used to connect to it. The default value is localhost, which allows only local TCP/IP "loopback" connections to be made. While client authentication (Chapter 19) allows fine-grained control over who can access the server, `listen_addresses` controls which interfaces accept connection attempts, which can help prevent repeated malicious connection requests on insecure network interfaces. This parameter can only be set at server start.

`port` (`integer`)

The TCP port the server listens on; 5432 by default. Note that the same port number is used for all IP addresses the server listens on. This parameter can only be set at server start.

`max_connections` (`integer`)

Determines the maximum number of concurrent connections to the database server. The default is typically 100 connections, but might be less if your kernel settings will not support it (as determined during initdb). This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`superuser_reserved_connections` (`integer`)

Determines the number of connection "slots" that are reserved for connections by PostgreSQL superusers. At most max_connections connections can ever be active simultaneously. Whenever the number of active concurrent connections is at least `max_connections` minus `superuser_reserved_connections`, new connections will be accepted only for superusers, and no new replication connections will be accepted.

The default value is three connections. The value must be less than the value of `max_connections`. This parameter can only be set at server start.

`unix_socket_directories` (`string`)

Specifies the directory of the Unix-domain socket(s) on which the server is to listen for connections from client applications. Multiple sockets can be created by listing multiple directories separated by commas. Whitespace between entries is ignored; surround a directory name with double quotes if you need to include whitespace or commas in the name. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. This parameter can only be set at server start.

In addition to the socket file itself, which is named `.s.PGSQL.`*`nnnn`* where *`nnnn`* is the server's port number, an ordinary file named `.s.PGSQL.`*`nnnn`*`.lock` will be created in each of the `unix_socket_directories` directories. Neither file should ever be removed manually.

This parameter is irrelevant on Windows, which does not have Unix-domain sockets.

`unix_socket_group` (`string`)

Sets the owning group of the Unix-domain socket(s). (The owning user of the sockets is always the user that starts the server.) In combination with the parameter `unix_socket_permissions` this can be used as an additional access control mechanism for Unix-domain connections. By default this is the empty string, which uses the default group of the server user. This parameter can only be set at server start.

This parameter is irrelevant on Windows, which does not have Unix-domain sockets.

`unix_socket_permissions` (`integer`)

Sets the access permissions of the Unix-domain socket(s). Unix-domain sockets use the usual Unix file system permission set. The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a `0` (zero).)

The default permissions are `0777`, meaning anyone can connect. Reasonable alternatives are `0770` (only user and group, see also `unix_socket_group`) and `0700` (only user). (Note that for a Unix-domain socket, only write permission matters, so there is no point in setting or revoking read or execute permissions.)

This access control mechanism is independent of the one described in Chapter 19.

This parameter can only be set at server start.

This parameter is irrelevant on systems, notably Solaris as of Solaris 10, that ignore socket permissions entirely. There, one can achieve a similar effect by pointing `unix_socket_directories` to a directory having search permission limited to the desired audience. This parameter is also irrelevant on Windows, which does not have Unix-domain sockets.

`bonjour` (`boolean`)

Enables advertising the server's existence via Bonjour. The default is off. This parameter can only be set at server start.

`bonjour_name` (`string`)

Specifies the Bonjour service name. The computer name is used if this parameter is set to the empty string `''` (which is the default). This parameter is ignored if the server was not compiled with Bonjour support. This parameter can only be set at server start.

`tcp_keepalives_idle` (`integer`)

Specifies the number of seconds of inactivity after which TCP should send a keepalive message to the client. A value of 0 uses the system default. This parameter is supported only on systems that support the `TCP_KEEPIDLE` or `TCP_KEEPALIVE` symbols, and on Windows; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

> **Note:** On Windows, a value of 0 will set this parameter to 2 hours, since Windows does not provide a way to read the system default value.

`tcp_keepalives_interval` (`integer`)

Specifies the number of seconds after which a TCP keepalive message that is not acknowledged by the client should be retransmitted. A value of 0 uses the system default. This parameter is supported only on systems that support the `TCP_KEEPINTVL` symbol, and on Windows; on other

systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note: On Windows, a value of 0 will set this parameter to 1 second, since Windows does not provide a way to read the system default value.

`tcp_keepalives_count` (`integer`)

Specifies the number of TCP keepalives that can be lost before the server's connection to the client is considered dead. A value of 0 uses the system default. This parameter is supported only on systems that support the `TCP_KEEPCNT` symbol; on other systems, it must be zero. In sessions connected via a Unix-domain socket, this parameter is ignored and always reads as zero.

Note: This parameter is not supported on Windows, and must be zero.

18.3.2. Security and Authentication

`authentication_timeout` (`integer`)

Maximum time to complete client authentication, in seconds. If a would-be client has not completed the authentication protocol in this much time, the server closes the connection. This prevents hung clients from occupying a connection indefinitely. The default is one minute (`1m`). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`ssl` (`boolean`)

Enables SSL connections. Please read Section 17.9 before using this. The default is `off`. This parameter can only be set at server start. SSL communication is only possible with TCP/IP connections.

`ssl_ca_file` (`string`)

Specifies the name of the file containing the SSL server certificate authority (CA). The default is empty, meaning no CA file is loaded, and client certificate verification is not performed. (In previous releases of PostgreSQL, the name of this file was hard-coded as `root.crt`.) Relative paths are relative to the data directory. This parameter can only be set at server start.

`ssl_cert_file` (`string`)

Specifies the name of the file containing the SSL server certificate. The default is `server.crt`. Relative paths are relative to the data directory. This parameter can only be set at server start.

`ssl_crl_file` (`string`)

Specifies the name of the file containing the SSL server certificate revocation list (CRL). The default is empty, meaning no CRL file is loaded. (In previous releases of PostgreSQL, the name of this file was hard-coded as `root.crl`.) Relative paths are relative to the data directory. This parameter can only be set at server start.

`ssl_key_file` (`string`)

Specifies the name of the file containing the SSL server private key. The default is `server.key`. Relative paths are relative to the data directory. This parameter can only be set at server start.

ssl_renegotiation_limit (integer)

Specifies how much data can flow over an SSL-encrypted connection before renegotiation of the session keys will take place. Renegotiation decreases an attacker's chances of doing cryptanalysis when large amounts of traffic can be examined, but it also carries a large performance penalty. The sum of sent and received traffic is used to check the limit. If this parameter is set to 0, renegotiation is disabled. The default is 512MB.

> **Note:** SSL libraries from before November 2009 are insecure when using SSL renegotiation, due to a vulnerability in the SSL protocol. As a stop-gap fix for this vulnerability, some vendors shipped SSL libraries incapable of doing renegotiation. If any such libraries are in use on the client or server, SSL renegotiation should be disabled.

ssl_ciphers (string)

Specifies a list of SSL cipher suites that are allowed to be used on secure connections. See the ciphers manual page in the OpenSSL package for the syntax of this setting and a list of supported values. The default value is HIGH:MEDIUM:+3DES:!aNULL. It is usually reasonable, unless you have specific security requirements.

Explanation of the default value:

HIGH

Cipher suites that use ciphers from HIGH group (e.g., AES, Camellia, 3DES)

MEDIUM

Cipher suites that use ciphers from MEDIUM group (e.g., RC4, SEED)

+3DES

The OpenSSL default order for HIGH is problematic because it orders 3DES higher than AES128. This is wrong because 3DES offers less security than AES128, and it is also much slower. +3DES reorders it after all other HIGH and MEDIUM ciphers.

!aNULL

Disables anonymous cipher suites that do no authentication. Such cipher suites are vulnerable to man-in-the-middle attacks and therefore should not be used.

Available cipher suite details will vary across OpenSSL versions. Use the command openssl ciphers -v 'HIGH:MEDIUM:+3DES:!aNULL' to see actual details for the currently installed OpenSSL version. Note that this list is filtered at run time based on the server key type.

ssl_prefer_server_ciphers (bool)

Specifies whether to use the server's SSL cipher preferences, rather than the client's. The default is true.

Older PostgreSQL versions do not have this setting and always use the client's preferences. This setting is mainly for backward compatibility with those versions. Using the server's preferences is usually better because it is more likely that the server is appropriately configured.

ssl_ecdh_curve (string)

Specifies the name of the curve to use in ECDH key exchange. It needs to be supported by all clients that connect. It does not need to be same curve as used by server's Elliptic Curve key. The default is prime256v1.

OpenSSL names for most common curves: `prime256v1` (NIST P-256), `secp384r1` (NIST P-384), `secp521r1` (NIST P-521).

The full list of available curves can be shown with the command `openssl ecparam -list_curves`. Not all of them are usable in TLS though.

`password_encryption` (`boolean`)

When a password is specified in CREATE USER or ALTER ROLE without writing either `ENCRYPTED` or `UNENCRYPTED`, this parameter determines whether the password is to be encrypted. The default is `on` (encrypt the password).

`krb_server_keyfile` (`string`)

Sets the location of the Kerberos server key file. See Section 19.3.3 for details. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`krb_caseins_users` (`boolean`)

Sets whether GSSAPI user names should be treated case-insensitively. The default is `off` (case sensitive). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`db_user_namespace` (`boolean`)

This parameter enables per-database user names. It is off by default. This parameter can only be set in the `postgresql.conf` file or on the server command line.

If this is on, you should create users as `username@dbname`. When `username` is passed by a connecting client, `@` and the database name are appended to the user name and that database-specific user name is looked up by the server. Note that when you create users with names containing `@` within the SQL environment, you will need to quote the user name.

With this parameter enabled, you can still create ordinary global users. Simply append `@` when specifying the user name in the client, e.g. `joe@`. The `@` will be stripped off before the user name is looked up by the server.

`db_user_namespace` causes the client's and server's user name representation to differ. Authentication checks are always done with the server's user name so authentication methods must be configured for the server's user name, not the client's. Because `md5` uses the user name as salt on both the client and server, `md5` cannot be used with `db_user_namespace`.

> **Note:** This feature is intended as a temporary measure until a complete solution is found. At that time, this option will be removed.

18.4. Resource Consumption

18.4.1. Memory

`shared_buffers` (`integer`)

Sets the amount of memory the database server uses for shared memory buffers. The default is typically 128 megabytes (`128MB`), but might be less if your kernel settings will not support it

(as determined during initdb). This setting must be at least 128 kilobytes. (Non-default values of BLCKSZ change the minimum.) However, settings significantly higher than the minimum are usually needed for good performance. This parameter can only be set at server start.

If you have a dedicated database server with 1GB or more of RAM, a reasonable starting value for shared_buffers is 25% of the memory in your system. There are some workloads where even large settings for shared_buffers are effective, but because PostgreSQL also relies on the operating system cache, it is unlikely that an allocation of more than 40% of RAM to shared_buffers will work better than a smaller amount. Larger settings for shared_buffers usually require a corresponding increase in checkpoint_segments, in order to spread out the process of writing large quantities of new or changed data over a longer period of time.

On systems with less than 1GB of RAM, a smaller percentage of RAM is appropriate, so as to leave adequate space for the operating system. Also, on Windows, large values for shared_buffers aren't as effective. You may find better results keeping the setting relatively low and using the operating system cache more instead. The useful range for shared_buffers on Windows systems is generally from 64MB to 512MB.

huge_pages (enum)

Enables/disables the use of huge memory pages. Valid values are try (the default), on, and off.

At present, this feature is supported only on Linux. The setting is ignored on other systems when set to try.

The use of huge pages results in smaller page tables and less CPU time spent on memory management, increasing performance. For more details, see Section 17.4.4.

With huge_pages set to try, the server will try to use huge pages, but fall back to using normal allocation if that fails. With on, failure to use huge pages will prevent the server from starting up. With off, huge pages will not be used.

temp_buffers (integer)

Sets the maximum number of temporary buffers used by each database session. These are session-local buffers used only for access to temporary tables. The default is eight megabytes (8MB). The setting can be changed within individual sessions, but only before the first use of temporary tables within the session; subsequent attempts to change the value will have no effect on that session.

A session will allocate temporary buffers as needed up to the limit given by temp_buffers. The cost of setting a large value in sessions that do not actually need many temporary buffers is only a buffer descriptor, or about 64 bytes, per increment in temp_buffers. However if a buffer is actually used an additional 8192 bytes will be consumed for it (or in general, BLCKSZ bytes).

max_prepared_transactions (integer)

Sets the maximum number of transactions that can be in the "prepared" state simultaneously (see PREPARE TRANSACTION). Setting this parameter to zero (which is the default) disables the prepared-transaction feature. This parameter can only be set at server start.

If you are not planning to use prepared transactions, this parameter should be set to zero to prevent accidental creation of prepared transactions. If you are using prepared transactions, you will probably want max_prepared_transactions to be at least as large as max_connections, so that every session can have a prepared transaction pending.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

work_mem (integer)

Specifies the amount of memory to be used by internal sort operations and hash tables before writing to temporary disk files. The value defaults to four megabytes (4MB). Note that for a complex query, several sort or hash operations might be running in parallel; each operation will be allowed to use as much memory as this value specifies before it starts to write data into temporary files. Also, several running sessions could be doing such operations concurrently. Therefore, the total memory used could be many times the value of work_mem; it is necessary to keep this fact in mind when choosing the value. Sort operations are used for ORDER BY, DISTINCT, and merge joins. Hash tables are used in hash joins, hash-based aggregation, and hash-based processing of IN subqueries.

maintenance_work_mem (integer)

Specifies the maximum amount of memory to be used by maintenance operations, such as VACUUM, CREATE INDEX, and ALTER TABLE ADD FOREIGN KEY. It defaults to 64 megabytes (64MB). Since only one of these operations can be executed at a time by a database session, and an installation normally doesn't have many of them running concurrently, it's safe to set this value significantly larger than work_mem. Larger settings might improve performance for vacuuming and for restoring database dumps.

Note that when autovacuum runs, up to autovacuum_max_workers times this memory may be allocated, so be careful not to set the default value too high. It may be useful to control for this by separately setting autovacuum_work_mem.

autovacuum_work_mem (integer)

Specifies the maximum amount of memory to be used by each autovacuum worker process. It defaults to -1, indicating that the value of maintenance_work_mem should be used instead. The setting has no effect on the behavior of VACUUM when run in other contexts.

max_stack_depth (integer)

Specifies the maximum safe depth of the server's execution stack. The ideal setting for this parameter is the actual stack size limit enforced by the kernel (as set by ulimit -s or local equivalent), less a safety margin of a megabyte or so. The safety margin is needed because the stack depth is not checked in every routine in the server, but only in key potentially-recursive routines such as expression evaluation. The default setting is two megabytes (2MB), which is conservatively small and unlikely to risk crashes. However, it might be too small to allow execution of complex functions. Only superusers can change this setting.

Setting max_stack_depth higher than the actual kernel limit will mean that a runaway recursive function can crash an individual backend process. On platforms where PostgreSQL can determine the kernel limit, the server will not allow this variable to be set to an unsafe value. However, not all platforms provide the information, so caution is recommended in selecting a value.

dynamic_shared_memory_type (enum)

Specifies the dynamic shared memory implementation that the server should use. Possible values are posix (for POSIX shared memory allocated using shm_open), sysv (for System V shared memory allocated via shmget), windows (for Windows shared memory), mmap (to simulate shared memory using memory-mapped files stored in the data directory), and none (to disable this feature). Not all values are supported on all platforms; the first supported option is the default for that platform. The use of the mmap option, which is not the default on any platform, is generally discouraged because the operating system may write modified pages back to disk repeatedly, increasing system I/O load; however, it may be useful for debugging, when the pg_dynshmem directory is stored on a RAM disk, or when other shared memory facilities are not available.

18.4.2. Disk

`temp_file_limit` (`integer`)

Specifies the maximum amount of disk space that a session can use for temporary files, such as sort and hash temporary files, or the storage file for a held cursor. A transaction attempting to exceed this limit will be canceled. The value is specified in kilobytes, and `-1` (the default) means no limit. Only superusers can change this setting.

This setting constrains the total space used at any instant by all temporary files used by a given PostgreSQL session. It should be noted that disk space used for explicit temporary tables, as opposed to temporary files used behind-the-scenes in query execution, does *not* count against this limit.

18.4.3. Kernel Resource Usage

`max_files_per_process` (`integer`)

Sets the maximum number of simultaneously open files allowed to each server subprocess. The default is one thousand files. If the kernel is enforcing a safe per-process limit, you don't need to worry about this setting. But on some platforms (notably, most BSD systems), the kernel will allow individual processes to open many more files than the system can actually support if many processes all try to open that many files. If you find yourself seeing "Too many open files" failures, try reducing this setting. This parameter can only be set at server start.

18.4.4. Cost-based Vacuum Delay

During the execution of VACUUM and ANALYZE commands, the system maintains an internal counter that keeps track of the estimated cost of the various I/O operations that are performed. When the accumulated cost reaches a limit (specified by `vacuum_cost_limit`), the process performing the operation will sleep for a short period of time, as specified by `vacuum_cost_delay`. Then it will reset the counter and continue execution.

The intent of this feature is to allow administrators to reduce the I/O impact of these commands on concurrent database activity. There are many situations where it is not important that maintenance commands like `VACUUM` and `ANALYZE` finish quickly; however, it is usually very important that these commands do not significantly interfere with the ability of the system to perform other database operations. Cost-based vacuum delay provides a way for administrators to achieve this.

This feature is disabled by default for manually issued `VACUUM` commands. To enable it, set the `vacuum_cost_delay` variable to a nonzero value.

`vacuum_cost_delay` (`integer`)

The length of time, in milliseconds, that the process will sleep when the cost limit has been exceeded. The default value is zero, which disables the cost-based vacuum delay feature. Positive values enable cost-based vacuuming. Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `vacuum_cost_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10.

When using cost-based vacuuming, appropriate values for `vacuum_cost_delay` are usually quite small, perhaps 10 or 20 milliseconds. Adjusting vacuum's resource consumption is best done by changing the other vacuum cost parameters.

`vacuum_cost_page_hit` (`integer`)

The estimated cost for vacuuming a buffer found in the shared buffer cache. It represents the cost to lock the buffer pool, lookup the shared hash table and scan the content of the page. The default value is one.

`vacuum_cost_page_miss` (`integer`)

The estimated cost for vacuuming a buffer that has to be read from disk. This represents the effort to lock the buffer pool, lookup the shared hash table, read the desired block in from the disk and scan its content. The default value is 10.

`vacuum_cost_page_dirty` (`integer`)

The estimated cost charged when vacuum modifies a block that was previously clean. It represents the extra I/O required to flush the dirty block out to disk again. The default value is 20.

`vacuum_cost_limit` (`integer`)

The accumulated cost that will cause the vacuuming process to sleep. The default value is 200.

Note: There are certain operations that hold critical locks and should therefore complete as quickly as possible. Cost-based vacuum delays do not occur during such operations. Therefore it is possible that the cost accumulates far higher than the specified limit. To avoid uselessly long delays in such cases, the actual delay is calculated as `vacuum_cost_delay` * `accumulated_balance` / `vacuum_cost_limit` with a maximum of `vacuum_cost_delay` * 4.

18.4.5. Background Writer

There is a separate server process called the *background writer*, whose function is to issue writes of "dirty" (new or modified) shared buffers. It writes shared buffers so server processes handling user queries seldom or never need to wait for a write to occur. However, the background writer does cause a net overall increase in I/O load, because while a repeatedly-dirtied page might otherwise be written only once per checkpoint interval, the background writer might write it several times as it is dirtied in the same interval. The parameters discussed in this subsection can be used to tune the behavior for local needs.

`bgwriter_delay` (`integer`)

Specifies the delay between activity rounds for the background writer. In each round the writer issues writes for some number of dirty buffers (controllable by the following parameters). It then sleeps for `bgwriter_delay` milliseconds, and repeats. When there are no dirty buffers in the buffer pool, though, it goes into a longer sleep regardless of `bgwriter_delay`. The default value is 200 milliseconds (`200ms`). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting `bgwriter_delay` to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`bgwriter_lru_maxpages` (`integer`)

In each round, no more than this many buffers will be written by the background writer. Setting this to zero disables background writing. (Note that checkpoints, which are managed by a separate, dedicated auxiliary process, are unaffected.) The default value is 100 buffers. This parameter can only be set in the `postgresql.conf` file or on the server command line.

bgwriter_lru_multiplier (floating point)

The number of dirty buffers written in each round is based on the number of new buffers that have been needed by server processes during recent rounds. The average recent need is multiplied by bgwriter_lru_multiplier to arrive at an estimate of the number of buffers that will be needed during the next round. Dirty buffers are written until there are that many clean, reusable buffers available. (However, no more than bgwriter_lru_maxpages buffers will be written per round.) Thus, a setting of 1.0 represents a "just in time" policy of writing exactly the number of buffers predicted to be needed. Larger values provide some cushion against spikes in demand, while smaller values intentionally leave writes to be done by server processes. The default is 2.0. This parameter can only be set in the postgresql.conf file or on the server command line.

Smaller values of bgwriter_lru_maxpages and bgwriter_lru_multiplier reduce the extra I/O load caused by the background writer, but make it more likely that server processes will have to issue writes for themselves, delaying interactive queries.

18.4.6. Asynchronous Behavior

effective_io_concurrency (integer)

Sets the number of concurrent disk I/O operations that PostgreSQL expects can be executed simultaneously. Raising this value will increase the number of I/O operations that any individual PostgreSQL session attempts to initiate in parallel. The allowed range is 1 to 1000, or zero to disable issuance of asynchronous I/O requests. Currently, this setting only affects bitmap heap scans.

A good starting point for this setting is the number of separate drives comprising a RAID 0 stripe or RAID 1 mirror being used for the database. (For RAID 5 the parity drive should not be counted.) However, if the database is often busy with multiple queries issued in concurrent sessions, lower values may be sufficient to keep the disk array busy. A value higher than needed to keep the disks busy will only result in extra CPU overhead.

For more exotic systems, such as memory-based storage or a RAID array that is limited by bus bandwidth, the correct value might be the number of I/O paths available. Some experimentation may be needed to find the best value.

Asynchronous I/O depends on an effective posix_fadvise function, which some operating systems lack. If the function is not present then setting this parameter to anything but zero will result in an error. On some operating systems (e.g., Solaris), the function is present but does not actually do anything.

max_worker_processes (integer)

Sets the maximum number of background processes that the system can support. This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

18.5. Write Ahead Log

For additional information on tuning these settings, see Section 29.4.

18.5.1. Settings

`wal_level` (`enum`)

`wal_level` determines how much information is written to the WAL. The default value is `minimal`, which writes only the information needed to recover from a crash or immediate shutdown. `archive` adds logging required for WAL archiving; `hot_standby` further adds information required to run read-only queries on a standby server; and, finally `logical` adds information necessary to support logical decoding. Each level includes the information logged at all lower levels. This parameter can only be set at server start.

In `minimal` level, WAL-logging of some bulk operations can be safely skipped, which can make those operations much faster (see Section 14.4.7). Operations in which this optimization can be applied include:

```
CREATE TABLE AS
CREATE INDEX
CLUSTER
```

`COPY` into tables that were created or truncated in the same transaction

But minimal WAL does not contain enough information to reconstruct the data from a base backup and the WAL logs, so `archive` or higher must be used to enable WAL archiving (archive_mode) and streaming replication.

In `hot_standby` level, the same information is logged as with `archive`, plus information needed to reconstruct the status of running transactions from the WAL. To enable read-only queries on a standby server, `wal_level` must be set to `hot_standby` or higher on the primary, and hot_standby must be enabled in the standby. It is thought that there is little measurable difference in performance between using `hot_standby` and `archive` levels, so feedback is welcome if any production impacts are noticeable.

In `logical` level, the same information is logged as with `hot_standby`, plus information needed to allow extracting logical changesets from the WAL. Using a level of `logical` will increase the WAL volume, particularly if many tables are configured for `REPLICA IDENTITY FULL` and many `UPDATE` and `DELETE` statements are executed.

`fsync` (`boolean`)

If this parameter is on, the PostgreSQL server will try to make sure that updates are physically written to disk, by issuing `fsync()` system calls or various equivalent methods (see wal_sync_method). This ensures that the database cluster can recover to a consistent state after an operating system or hardware crash.

While turning off `fsync` is often a performance benefit, this can result in unrecoverable data corruption in the event of a power failure or system crash. Thus it is only advisable to turn off `fsync` if you can easily recreate your entire database from external data.

Examples of safe circumstances for turning off `fsync` include the initial loading of a new database cluster from a backup file, using a database cluster for processing a batch of data after which the database will be thrown away and recreated, or for a read-only database clone which gets recreated frequently and is not used for failover. High quality hardware alone is not a sufficient justification for turning off `fsync`.

For reliable recovery when changing `fsync` off to on, it is necessary to force all modified buffers in the kernel to durable storage. This can be done while the cluster is shutdown or while fsync is on by running `initdb --sync-only`, running `sync`, unmounting the file system, or rebooting the server.

In many situations, turning off synchronous_commit for noncritical transactions can provide much of the potential performance benefit of turning off fsync, without the attendant risks of data corruption.

fsync can only be set in the postgresql.conf file or on the server command line. If you turn this parameter off, also consider turning off full_page_writes.

synchronous_commit (enum)

Specifies whether transaction commit will wait for WAL records to be written to disk before the command returns a "success" indication to the client. Valid values are on, remote_write, local, and off. The default, and safe, setting is on. When off, there can be a delay between when success is reported to the client and when the transaction is really guaranteed to be safe against a server crash. (The maximum delay is three times wal_writer_delay.) Unlike fsync, setting this parameter to off does not create any risk of database inconsistency: an operating system or database crash might result in some recent allegedly-committed transactions being lost, but the database state will be just the same as if those transactions had been aborted cleanly. So, turning synchronous_commit off can be a useful alternative when performance is more important than exact certainty about the durability of a transaction. For more discussion see Section 29.3.

If synchronous_standby_names is set, this parameter also controls whether or not transaction commits will wait for the transaction's WAL records to be replicated to the standby server. When set to on, commits will wait until a reply from the current synchronous standby indicates it has received the commit record of the transaction and flushed it to disk. This ensures the transaction will not be lost unless both primary and standby suffer corruption of their database storage. When set to remote_write, commits will wait until a reply from the current synchronous standby indicates it has received the commit record of the transaction and written it out to the standby's operating system, but the data has not necessarily reached stable storage on the standby. This setting is sufficient to ensure data preservation even if the standby instance of PostgreSQL were to crash, but not if the standby suffers an operating-system-level crash.

When synchronous replication is in use, it will normally be sensible either to wait for both local flush to disk and replication of WAL records, or to allow the transaction to commit asynchronously. However, the setting local is available for transactions that wish to wait for local flush to disk, but not synchronous replication. If synchronous_standby_names is not set, the settings on, remote_write and local all provide the same synchronization level: transaction commits only wait for local flush to disk.

This parameter can be changed at any time; the behavior for any one transaction is determined by the setting in effect when it commits. It is therefore possible, and useful, to have some transactions commit synchronously and others asynchronously. For example, to make a single multistatement transaction commit asynchronously when the default is the opposite, issue SET LOCAL synchronous_commit TO OFF within the transaction.

wal_sync_method (enum)

Method used for forcing WAL updates out to disk. If fsync is off then this setting is irrelevant, since WAL file updates will not be forced out at all. Possible values are:

- open_datasync (write WAL files with open() option O_DSYNC)
- fdatasync (call fdatasync() at each commit)
- fsync (call fsync() at each commit)
- fsync_writethrough (call fsync() at each commit, forcing write-through of any disk write cache)
- open_sync (write WAL files with open() option O_SYNC)

The open_* options also use O_DIRECT if available. Not all of these choices are available on all platforms. The default is the first method in the above list that is supported by the platform, except that fdatasync is the default on Linux. The default is not necessarily ideal; it might be necessary to change this setting or other aspects of your system configuration in order to create a crash-safe configuration or achieve optimal performance. These aspects are discussed in Section 29.1. This parameter can only be set in the postgresql.conf file or on the server command line.

full_page_writes (boolean)

When this parameter is on, the PostgreSQL server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint. This is needed because a page write that is in process during an operating system crash might be only partially completed, leading to an on-disk page that contains a mix of old and new data. The row-level change data normally stored in WAL will not be enough to completely restore such a page during post-crash recovery. Storing the full page image guarantees that the page can be correctly restored, but at the price of increasing the amount of data that must be written to WAL. (Because WAL replay always starts from a checkpoint, it is sufficient to do this during the first change of each page after a checkpoint. Therefore, one way to reduce the cost of full-page writes is to increase the checkpoint interval parameters.)

Turning this parameter off speeds normal operation, but might lead to either unrecoverable data corruption, or silent data corruption, after a system failure. The risks are similar to turning off fsync, though smaller, and it should be turned off only based on the same circumstances recommended for that parameter.

Turning off this parameter does not affect use of WAL archiving for point-in-time recovery (PITR) (see Section 24.3).

This parameter can only be set in the postgresql.conf file or on the server command line. The default is on.

wal_log_hints (boolean)

When this parameter is on, the PostgreSQL server writes the entire content of each disk page to WAL during the first modification of that page after a checkpoint, even for non-critical modifications of so-called hint bits.

If data checksums are enabled, hint bit updates are always WAL-logged and this setting is ignored. You can use this setting to test how much extra WAL-logging would occur if your database had data checksums enabled.

This parameter can only be set at server start. The default value is off.

wal_buffers (integer)

The amount of shared memory used for WAL data that has not yet been written to disk. The default setting of -1 selects a size equal to 1/32nd (about 3%) of shared_buffers, but not less than 64kB nor more than the size of one WAL segment, typically 16MB. This value can be set manually if the automatic choice is too large or too small, but any positive value less than 32kB will be treated as 32kB. This parameter can only be set at server start.

The contents of the WAL buffers are written out to disk at every transaction commit, so extremely large values are unlikely to provide a significant benefit. However, setting this value to at least a few megabytes can improve write performance on a busy server where many clients are committing at once. The auto-tuning selected by the default setting of -1 should give reasonable results in most cases.

wal_writer_delay (integer)

Specifies the delay between activity rounds for the WAL writer. In each round the writer will flush WAL to disk. It then sleeps for wal_writer_delay milliseconds, and repeats. The default value is 200 milliseconds (200ms). Note that on many systems, the effective resolution of sleep delays is 10 milliseconds; setting wal_writer_delay to a value that is not a multiple of 10 might have the same results as setting it to the next higher multiple of 10. This parameter can only be set in the postgresql.conf file or on the server command line.

commit_delay (integer)

commit_delay adds a time delay, measured in microseconds, before a WAL flush is initiated. This can improve group commit throughput by allowing a larger number of transactions to commit via a single WAL flush, if system load is high enough that additional transactions become ready to commit within the given interval. However, it also increases latency by up to commit_delay microseconds for each WAL flush. Because the delay is just wasted if no other transactions become ready to commit, a delay is only performed if at least commit_siblings other transactions are active when a flush is about to be initiated. Also, no delays are performed if fsync is disabled. The default commit_delay is zero (no delay). Only superusers can change this setting.

In PostgreSQL releases prior to 9.3, commit_delay behaved differently and was much less effective: it affected only commits, rather than all WAL flushes, and waited for the entire configured delay even if the WAL flush was completed sooner. Beginning in PostgreSQL 9.3, the first process that becomes ready to flush waits for the configured interval, while subsequent processes wait only until the leader completes the flush operation.

commit_siblings (integer)

Minimum number of concurrent open transactions to require before performing the commit_delay delay. A larger value makes it more probable that at least one other transaction will become ready to commit during the delay interval. The default is five transactions.

18.5.2. Checkpoints

checkpoint_segments (integer)

Maximum number of log file segments between automatic WAL checkpoints (each segment is normally 16 megabytes). The default is three segments. Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the postgresql.conf file or on the server command line.

checkpoint_timeout (integer)

Maximum time between automatic WAL checkpoints, in seconds. The default is five minutes (5min). Increasing this parameter can increase the amount of time needed for crash recovery. This parameter can only be set in the postgresql.conf file or on the server command line.

checkpoint_completion_target (floating point)

Specifies the target of checkpoint completion, as a fraction of total time between checkpoints. The default is 0.5. This parameter can only be set in the postgresql.conf file or on the server command line.

checkpoint_warning (integer)

Write a message to the server log if checkpoints caused by the filling of checkpoint segment files happen closer together than this many seconds (which suggests that checkpoint_segments

ought to be raised). The default is 30 seconds (30s). Zero disables the warning. No warnings will be generated if checkpoint_timeout is less than checkpoint_warning. This parameter can only be set in the postgresql.conf file or on the server command line.

18.5.3. Archiving

archive_mode (boolean)

When archive_mode is enabled, completed WAL segments are sent to archive storage by setting archive_command. archive_mode and archive_command are separate variables so that archive_command can be changed without leaving archiving mode. This parameter can only be set at server start. archive_mode cannot be enabled when wal_level is set to minimal.

archive_command (string)

The local shell command to execute to archive a completed WAL file segment. Any %p in the string is replaced by the path name of the file to archive, and any %f is replaced by only the file name. (The path name is relative to the working directory of the server, i.e., the cluster's data directory.) Use %% to embed an actual % character in the command. It is important for the command to return a zero exit status only if it succeeds. For more information see Section 24.3.1.

This parameter can only be set in the postgresql.conf file or on the server command line. It is ignored unless archive_mode was enabled at server start. If archive_command is an empty string (the default) while archive_mode is enabled, WAL archiving is temporarily disabled, but the server continues to accumulate WAL segment files in the expectation that a command will soon be provided. Setting archive_command to a command that does nothing but return true, e.g. /bin/true (REM on Windows), effectively disables archiving, but also breaks the chain of WAL files needed for archive recovery, so it should only be used in unusual circumstances.

archive_timeout (integer)

The archive_command is only invoked for completed WAL segments. Hence, if your server generates little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To limit how old unarchived data can be, you can set archive_timeout to force the server to switch to a new WAL segment file periodically. When this parameter is greater than zero, the server will switch to a new segment file whenever this many seconds have elapsed since the last segment file switch, and there has been any database activity, including a single checkpoint. (Increasing checkpoint_timeout will reduce unnecessary checkpoints on an idle system.) Note that archived files that are closed early due to a forced switch are still the same length as completely full files. Therefore, it is unwise to use a very short archive_timeout — it will bloat your archive storage. archive_timeout settings of a minute or so are usually reasonable. You should consider using streaming replication, instead of archiving, if you want data to be copied off the master server more quickly than that. This parameter can only be set in the postgresql.conf file or on the server command line.

18.6. Replication

These settings control the behavior of the built-in *streaming replication* feature (see Section 25.2.5). Servers will be either a Master or a Standby server. Masters can send data, while Standby(s) are always receivers of replicated data. When cascading replication (see Section 25.2.7) is used, Standby

server(s) can also be senders, as well as receivers. Parameters are mainly for Sending and Standby servers, though some parameters have meaning only on the Master server. Settings may vary across the cluster without problems if that is required.

18.6.1. Sending Server(s)

These parameters can be set on any server that is to send replication data to one or more standby servers. The master is always a sending server, so these parameters must always be set on the master. The role and meaning of these parameters does not change after a standby becomes the master.

`max_wal_senders` (`integer`)

Specifies the maximum number of concurrent connections from standby servers or streaming base backup clients (i.e., the maximum number of simultaneously running WAL sender processes). The default is zero, meaning replication is disabled. WAL sender processes count towards the total number of connections, so the parameter cannot be set higher than max_connections. Abrupt streaming client disconnection might cause an orphaned connection slot until a timeout is reached, so this parameter should be set slightly higher than the maximum number of expected clients so disconnected clients can immediately reconnect. This parameter can only be set at server start. `wal_level` must be set to `archive` or higher to allow connections from standby servers.

`max_replication_slots` (`integer`)

Specifies the maximum number of replication slots (see Section 25.2.6) that the server can support. The default is zero. This parameter can only be set at server start. `wal_level` must be set to `archive` or higher to allow replication slots to be used. Setting it to a lower value than the number of currently existing replication slots will prevent the server from starting.

`wal_keep_segments` (`integer`)

Specifies the minimum number of past log file segments kept in the `pg_xlog` directory, in case a standby server needs to fetch them for streaming replication. Each segment is normally 16 megabytes. If a standby server connected to the sending server falls behind by more than `wal_keep_segments` segments, the sending server might remove a WAL segment still needed by the standby, in which case the replication connection will be terminated. Downstream connections will also eventually fail as a result. (However, the standby server can recover by fetching the segment from archive, if WAL archiving is in use.)

This sets only the minimum number of segments retained in `pg_xlog`; the system might need to retain more segments for WAL archival or to recover from a checkpoint. If `wal_keep_segments` is zero (the default), the system doesn't keep any extra segments for standby purposes, so the number of old WAL segments available to standby servers is a function of the location of the previous checkpoint and status of WAL archiving. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`wal_sender_timeout` (`integer`)

Terminate replication connections that are inactive longer than the specified number of milliseconds. This is useful for the sending server to detect a standby crash or network outage. A value of zero disables the timeout mechanism. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default value is 60 seconds.

18.6.2. Master Server

These parameters can be set on the master/primary server that is to send replication data to one or more standby servers. Note that in addition to these parameters, wal_level must be set appropriately on the master server, and optionally WAL archiving can be enabled as well (see Section 18.5.3). The values of these parameters on standby servers are irrelevant, although you may wish to set them there in preparation for the possibility of a standby becoming the master.

`synchronous_standby_names` (`string`)

Specifies a comma-separated list of standby names that can support *synchronous replication*, as described in Section 25.2.8. At any one time there will be at most one active synchronous standby; transactions waiting for commit will be allowed to proceed after this standby server confirms receipt of their data. The synchronous standby will be the first standby named in this list that is both currently connected and streaming data in real-time (as shown by a state of `streaming` in the `pg_stat_replication` view). Other standby servers appearing later in this list represent potential synchronous standbys. If the current synchronous standby disconnects for whatever reason, it will be replaced immediately with the next-highest-priority standby. Specifying more than one standby name can allow very high availability.

The name of a standby server for this purpose is the `application_name` setting of the standby, as set in the `primary_conninfo` of the standby's WAL receiver. There is no mechanism to enforce uniqueness. In case of duplicates one of the matching standbys will be chosen to be the synchronous standby, though exactly which one is indeterminate. The special entry `*` matches any `application_name`, including the default application name of `walreceiver`.

If no synchronous standby names are specified here, then synchronous replication is not enabled and transaction commits will not wait for replication. This is the default configuration. Even when synchronous replication is enabled, individual transactions can be configured not to wait for replication by setting the synchronous_commit parameter to `local` or `off`.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`vacuum_defer_cleanup_age` (`integer`)

Specifies the number of transactions by which `VACUUM` and HOT updates will defer cleanup of dead row versions. The default is zero transactions, meaning that dead row versions can be removed as soon as possible, that is, as soon as they are no longer visible to any open transaction. You may wish to set this to a non-zero value on a primary server that is supporting hot standby servers, as described in Section 25.5. This allows more time for queries on the standby to complete without incurring conflicts due to early cleanup of rows. However, since the value is measured in terms of number of write transactions occurring on the primary server, it is difficult to predict just how much additional grace time will be made available to standby queries. This parameter can only be set in the `postgresql.conf` file or on the server command line.

You should also consider setting `hot_standby_feedback` on standby server(s) as an alternative to using this parameter.

18.6.3. Standby Servers

These settings control the behavior of a standby server that is to receive replication data. Their values on the master server are irrelevant.

hot_standby (boolean)

Specifies whether or not you can connect and run queries during recovery, as described in Section 25.5. The default value is off. This parameter can only be set at server start. It only has effect during archive recovery or in standby mode.

max_standby_archive_delay (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 25.5.2. max_standby_archive_delay applies when WAL data is being read from WAL archive (and is therefore not current). The default is 30 seconds. Units are milliseconds if not specified. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the postgresql.conf file or on the server command line.

Note that max_standby_archive_delay is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply any one WAL segment's data. Thus, if one query has resulted in significant delay earlier in the WAL segment, subsequent conflicting queries will have much less grace time.

max_standby_streaming_delay (integer)

When Hot Standby is active, this parameter determines how long the standby server should wait before canceling standby queries that conflict with about-to-be-applied WAL entries, as described in Section 25.5.2. max_standby_streaming_delay applies when WAL data is being received via streaming replication. The default is 30 seconds. Units are milliseconds if not specified. A value of -1 allows the standby to wait forever for conflicting queries to complete. This parameter can only be set in the postgresql.conf file or on the server command line.

Note that max_standby_streaming_delay is not the same as the maximum length of time a query can run before cancellation; rather it is the maximum total time allowed to apply WAL data once it has been received from the primary server. Thus, if one query has resulted in significant delay, subsequent conflicting queries will have much less grace time until the standby server has caught up again.

wal_receiver_status_interval (integer)

Specifies the minimum frequency for the WAL receiver process on the standby to send information about replication progress to the primary or upstream standby, where it can be seen using the pg_stat_replication view. The standby will report the last transaction log position it has written, the last position it has flushed to disk, and the last position it has applied. This parameter's value is the maximum interval, in seconds, between reports. Updates are sent each time the write or flush positions change, or at least as often as specified by this parameter. Thus, the apply position may lag slightly behind the true position. Setting this parameter to zero disables status updates completely. This parameter can only be set in the postgresql.conf file or on the server command line. The default value is 10 seconds.

hot_standby_feedback (boolean)

Specifies whether or not a hot standby will send feedback to the primary or upstream standby about queries currently executing on the standby. This parameter can be used to eliminate query cancels caused by cleanup records, but can cause database bloat on the primary for some workloads. Feedback messages will not be sent more frequently than once per wal_receiver_status_interval. The default value is off. This parameter can only be set in the postgresql.conf file or on the server command line.

If cascaded replication is in use the feedback is passed upstream until it eventually reaches the primary. Standbys make no other use of feedback they receive other than to pass upstream.

`wal_receiver_timeout` (`integer`)

Terminate replication connections that are inactive longer than the specified number of milliseconds. This is useful for the receiving standby server to detect a primary node crash or network outage. A value of zero disables the timeout mechanism. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default value is 60 seconds.

18.7. Query Planning

18.7.1. Planner Method Configuration

These configuration parameters provide a crude method of influencing the query plans chosen by the query optimizer. If the default plan chosen by the optimizer for a particular query is not optimal, a *temporary* solution is to use one of these configuration parameters to force the optimizer to choose a different plan. Better ways to improve the quality of the plans chosen by the optimizer include adjusting the planer cost constants (see Section 18.7.2), running ANALYZE manually, increasing the value of the default_statistics_target configuration parameter, and increasing the amount of statistics collected for specific columns using `ALTER TABLE SET STATISTICS`.

`enable_bitmapscan` (`boolean`)

Enables or disables the query planner's use of bitmap-scan plan types. The default is `on`.

`enable_hashagg` (`boolean`)

Enables or disables the query planner's use of hashed aggregation plan types. The default is `on`.

`enable_hashjoin` (`boolean`)

Enables or disables the query planner's use of hash-join plan types. The default is `on`.

`enable_indexscan` (`boolean`)

Enables or disables the query planner's use of index-scan plan types. The default is `on`.

`enable_indexonlyscan` (`boolean`)

Enables or disables the query planner's use of index-only-scan plan types. The default is `on`.

`enable_material` (`boolean`)

Enables or disables the query planner's use of materialization. It is impossible to suppress materialization entirely, but turning this variable off prevents the planner from inserting materialize nodes except in cases where it is required for correctness. The default is `on`.

`enable_mergejoin` (`boolean`)

Enables or disables the query planner's use of merge-join plan types. The default is `on`.

`enable_nestloop` (`boolean`)

Enables or disables the query planner's use of nested-loop join plans. It is impossible to suppress nested-loop joins entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_seqscan` (`boolean`)

Enables or disables the query planner's use of sequential scan plan types. It is impossible to suppress sequential scans entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_sort` (`boolean`)

Enables or disables the query planner's use of explicit sort steps. It is impossible to suppress explicit sorts entirely, but turning this variable off discourages the planner from using one if there are other methods available. The default is `on`.

`enable_tidscan` (`boolean`)

Enables or disables the query planner's use of TID scan plan types. The default is `on`.

18.7.2. Planner Cost Constants

The *cost* variables described in this section are measured on an arbitrary scale. Only their relative values matter, hence scaling them all up or down by the same factor will result in no change in the planner's choices. By default, these cost variables are based on the cost of sequential page fetches; that is, `seq_page_cost` is conventionally set to `1.0` and the other cost variables are set with reference to that. But you can use a different scale if you prefer, such as actual execution times in milliseconds on a particular machine.

Note: Unfortunately, there is no well-defined method for determining ideal values for the cost variables. They are best treated as averages over the entire mix of queries that a particular installation will receive. This means that changing them on the basis of just a few experiments is very risky.

`seq_page_cost` (`floating point`)

Sets the planner's estimate of the cost of a disk page fetch that is part of a series of sequential fetches. The default is 1.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see ALTER TABLESPACE).

`random_page_cost` (`floating point`)

Sets the planner's estimate of the cost of a non-sequentially-fetched disk page. The default is 4.0. This value can be overridden for tables and indexes in a particular tablespace by setting the tablespace parameter of the same name (see ALTER TABLESPACE).

Reducing this value relative to `seq_page_cost` will cause the system to prefer index scans; raising it will make index scans look relatively more expensive. You can raise or lower both values together to change the importance of disk I/O costs relative to CPU costs, which are described by the following parameters.

Random access to mechanical disk storage is normally much more expensive than four times sequential access. However, a lower default is used (4.0) because the majority of random accesses to disk, such as indexed reads, are assumed to be in cache. The default value can be thought of as modeling random access as 40 times slower than sequential, while expecting 90% of random reads to be cached.

If you believe a 90% cache rate is an incorrect assumption for your workload, you can increase random_page_cost to better reflect the true cost of random storage reads. Correspondingly, if your data is likely to be completely in cache, such as when the database is smaller than the total server memory, decreasing random_page_cost can be appropriate. Storage that has a low random read cost relative to sequential, e.g. solid-state drives, might also be better modeled with a lower value for random_page_cost.

> **Tip:** Although the system will let you set `random_page_cost` to less than `seq_page_cost`, it is not physically sensible to do so. However, setting them equal makes sense if the database is entirely cached in RAM, since in that case there is no penalty for touching pages out of sequence. Also, in a heavily-cached database you should lower both values relative to the CPU parameters, since the cost of fetching a page already in RAM is much smaller than it would normally be.

`cpu_tuple_cost` (`floating point`)

Sets the planner's estimate of the cost of processing each row during a query. The default is 0.01.

`cpu_index_tuple_cost` (`floating point`)

Sets the planner's estimate of the cost of processing each index entry during an index scan. The default is 0.005.

`cpu_operator_cost` (`floating point`)

Sets the planner's estimate of the cost of processing each operator or function executed during a query. The default is 0.0025.

`effective_cache_size` (`integer`)

Sets the planner's assumption about the effective size of the disk cache that is available to a single query. This is factored into estimates of the cost of using an index; a higher value makes it more likely index scans will be used, a lower value makes it more likely sequential scans will be used. When setting this parameter you should consider both PostgreSQL's shared buffers and the portion of the kernel's disk cache that will be used for PostgreSQL data files. Also, take into account the expected number of concurrent queries on different tables, since they will have to share the available space. This parameter has no effect on the size of shared memory allocated by PostgreSQL, nor does it reserve kernel disk cache; it is used only for estimation purposes. The system also does not assume data remains in the disk cache between queries. The default is 4 gigabytes (`4GB`).

18.7.3. Genetic Query Optimizer

The genetic query optimizer (GEQO) is an algorithm that does query planning using heuristic searching. This reduces planning time for complex queries (those joining many relations), at the cost of producing plans that are sometimes inferior to those found by the normal exhaustive-search algorithm. For more information see Chapter 54.

`geqo` (`boolean`)

Enables or disables genetic query optimization. This is on by default. It is usually best not to turn it off in production; the `geqo_threshold` variable provides more granular control of GEQO.

`geqo_threshold` (`integer`)

Use genetic query optimization to plan queries with at least this many `FROM` items involved. (Note that a `FULL OUTER JOIN` construct counts as only one `FROM` item.) The default is 12. For simpler queries it is usually best to use the regular, exhaustive-search planner, but for queries with many tables the exhaustive search takes too long, often longer than the penalty of executing a suboptimal plan. Thus, a threshold on the size of the query is a convenient way to manage use of GEQO.

geqo_effort (integer)

Controls the trade-off between planning time and query plan quality in GEQO. This variable must be an integer in the range from 1 to 10. The default value is five. Larger values increase the time spent doing query planning, but also increase the likelihood that an efficient query plan will be chosen.

geqo_effort doesn't actually do anything directly; it is only used to compute the default values for the other variables that influence GEQO behavior (described below). If you prefer, you can set the other parameters by hand instead.

geqo_pool_size (integer)

Controls the pool size used by GEQO, that is the number of individuals in the genetic population. It must be at least two, and useful values are typically 100 to 1000. If it is set to zero (the default setting) then a suitable value is chosen based on geqo_effort and the number of tables in the query.

geqo_generations (integer)

Controls the number of generations used by GEQO, that is the number of iterations of the algorithm. It must be at least one, and useful values are in the same range as the pool size. If it is set to zero (the default setting) then a suitable value is chosen based on geqo_pool_size.

geqo_selection_bias (floating point)

Controls the selection bias used by GEQO. The selection bias is the selective pressure within the population. Values can be from 1.50 to 2.00; the latter is the default.

geqo_seed (floating point)

Controls the initial value of the random number generator used by GEQO to select random paths through the join order search space. The value can range from zero (the default) to one. Varying the value changes the set of join paths explored, and may result in a better or worse best path being found.

18.7.4. Other Planner Options

default_statistics_target (integer)

Sets the default statistics target for table columns without a column-specific target set via ALTER TABLE SET STATISTICS. Larger values increase the time needed to do ANALYZE, but might improve the quality of the planner's estimates. The default is 100. For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

constraint_exclusion (enum)

Controls the query planner's use of table constraints to optimize queries. The allowed values of constraint_exclusion are on (examine constraints for all tables), off (never examine constraints), and partition (examine constraints only for inheritance child tables and UNION ALL subqueries). partition is the default setting. It is often used with inheritance and partitioned tables to improve performance.

When this parameter allows it for a particular table, the planner compares query conditions with the table's CHECK constraints, and omits scanning tables for which the conditions contradict the constraints. For example:

```
CREATE TABLE parent(key integer, ...);
CREATE TABLE child1000(check (key between 1000 and 1999)) INHERITS(parent);
CREATE TABLE child2000(check (key between 2000 and 2999)) INHERITS(parent);
```

```
...
SELECT * FROM parent WHERE key = 2400;
```

With constraint exclusion enabled, this `SELECT` will not scan `child1000` at all, improving performance.

Currently, constraint exclusion is enabled by default only for cases that are often used to implement table partitioning. Turning it on for all tables imposes extra planning overhead that is quite noticeable on simple queries, and most often will yield no benefit for simple queries. If you have no partitioned tables you might prefer to turn it off entirely.

Refer to Section 5.9.4 for more information on using constraint exclusion and partitioning.

`cursor_tuple_fraction` (`floating point`)

Sets the planner's estimate of the fraction of a cursor's rows that will be retrieved. The default is 0.1. Smaller values of this setting bias the planner towards using "fast start" plans for cursors, which will retrieve the first few rows quickly while perhaps taking a long time to fetch all rows. Larger values put more emphasis on the total estimated time. At the maximum setting of 1.0, cursors are planned exactly like regular queries, considering only the total estimated time and not how soon the first rows might be delivered.

`from_collapse_limit` (`integer`)

The planner will merge sub-queries into upper queries if the resulting `FROM` list would have no more than this many items. Smaller values reduce planning time but might yield inferior query plans. The default is eight. For more information see Section 14.3.

Setting this value to geqo_threshold or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 18.7.3.

`join_collapse_limit` (`integer`)

The planner will rewrite explicit `JOIN` constructs (except `FULL JOIN`s) into lists of `FROM` items whenever a list of no more than this many items would result. Smaller values reduce planning time but might yield inferior query plans.

By default, this variable is set the same as `from_collapse_limit`, which is appropriate for most uses. Setting it to 1 prevents any reordering of explicit `JOIN`s. Thus, the explicit join order specified in the query will be the actual order in which the relations are joined. Because the query planner does not always choose the optimal join order, advanced users can elect to temporarily set this variable to 1, and then specify the join order they desire explicitly. For more information see Section 14.3.

Setting this value to geqo_threshold or more may trigger use of the GEQO planner, resulting in non-optimal plans. See Section 18.7.3.

18.8. Error Reporting and Logging

18.8.1. Where To Log

`log_destination` (`string`)

PostgreSQL supports several methods for logging server messages, including stderr, csvlog and syslog. On Windows, eventlog is also supported. Set this parameter to a list of desired log desti-

nations separated by commas. The default is to log to stderr only. This parameter can only be set in the `postgresql.conf` file or on the server command line.

If csvlog is included in `log_destination`, log entries are output in "comma separated value" (CSV) format, which is convenient for loading logs into programs. See Section 18.8.4 for details. logging_collector must be enabled to generate CSV-format log output.

> **Note:** On most Unix systems, you will need to alter the configuration of your system's syslog daemon in order to make use of the syslog option for `log_destination`. PostgreSQL can log to syslog facilities `LOCAL0` through `LOCAL7` (see syslog_facility), but the default syslog configuration on most platforms will discard all such messages. You will need to add something like:
>
> ```
> local0.*    /var/log/postgresql
> ```
>
> to the syslog daemon's configuration file to make it work.
>
> On Windows, when you use the `eventlog` option for `log_destination`, you should register an event source and its library with the operating system so that the Windows Event Viewer can display event log messages cleanly. See Section 17.11 for details.

`logging_collector` (`boolean`)

This parameter enables the *logging collector*, which is a background process that captures log messages sent to stderr and redirects them into log files. This approach is often more useful than logging to syslog, since some types of messages might not appear in syslog output. (One common example is dynamic-linker failure messages; another is error messages produced by scripts such as `archive_command`.) This parameter can only be set at server start.

> **Note:** It is possible to log to stderr without using the logging collector; the log messages will just go to wherever the server's stderr is directed. However, that method is only suitable for low log volumes, since it provides no convenient way to rotate log files. Also, on some platforms not using the logging collector can result in lost or garbled log output, because multiple processes writing concurrently to the same log file can overwrite each other's output.

> **Note:** The logging collector is designed to never lose messages. This means that in case of extremely high load, server processes could be blocked while trying to send additional log messages when the collector has fallen behind. In contrast, syslog prefers to drop messages if it cannot write them, which means it may fail to log some messages in such cases but it will not block the rest of the system.

`log_directory` (`string`)

When `logging_collector` is enabled, this parameter determines the directory in which log files will be created. It can be specified as an absolute path, or relative to the cluster data directory. This parameter can only be set in the `postgresql.conf` file or on the server command line. The default is `pg_log`.

`log_filename` (`string`)

When `logging_collector` is enabled, this parameter sets the file names of the created log files. The value is treated as a `strftime` pattern, so `%`-escapes can be used to specify time-varying file names. (Note that if there are any time-zone-dependent `%`-escapes, the computation is done in the zone specified by log_timezone.) The supported `%`-escapes are similar to

those listed in the Open Group's strftime [1] specification. Note that the system's strftime is not used directly, so platform-specific (nonstandard) extensions do not work. The default is `postgresql-%Y-%m-%d_%H%M%S.log`.

If you specify a file name without escapes, you should plan to use a log rotation utility to avoid eventually filling the entire disk. In releases prior to 8.4, if no `%` escapes were present, PostgreSQL would append the epoch of the new log file's creation time, but this is no longer the case.

If CSV-format output is enabled in `log_destination`, `.csv` will be appended to the timestamped log file name to create the file name for CSV-format output. (If `log_filename` ends in `.log`, the suffix is replaced instead.)

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_file_mode` (`integer`)

On Unix systems this parameter sets the permissions for log files when `logging_collector` is enabled. (On Microsoft Windows this parameter is ignored.) The parameter value is expected to be a numeric mode specified in the format accepted by the `chmod` and `umask` system calls. (To use the customary octal format the number must start with a `0` (zero).)

The default permissions are `0600`, meaning only the server owner can read or write the log files. The other commonly useful setting is `0640`, allowing members of the owner's group to read the files. Note however that to make use of such a setting, you'll need to alter log_directory to store the files somewhere outside the cluster data directory. In any case, it's unwise to make the log files world-readable, since they might contain sensitive data.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_rotation_age` (`integer`)

When `logging_collector` is enabled, this parameter determines the maximum lifetime of an individual log file. After this many minutes have elapsed, a new log file will be created. Set to zero to disable time-based creation of new log files. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_rotation_size` (`integer`)

When `logging_collector` is enabled, this parameter determines the maximum size of an individual log file. After this many kilobytes have been emitted into a log file, a new log file will be created. Set to zero to disable size-based creation of new log files. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`log_truncate_on_rotation` (`boolean`)

When `logging_collector` is enabled, this parameter will cause PostgreSQL to truncate (overwrite), rather than append to, any existing log file of the same name. However, truncation will occur only when a new file is being opened due to time-based rotation, not during server startup or size-based rotation. When off, pre-existing files will be appended to in all cases. For example, using this setting in combination with a `log_filename` like `postgresql-%H.log` would result in generating twenty-four hourly log files and then cyclically overwriting them. This parameter can only be set in the `postgresql.conf` file or on the server command line.

Example: To keep 7 days of logs, one log file per day named `server_log.Mon`, `server_log.Tue`, etc, and automatically overwrite last week's log with this week's log, set `log_filename` to `server_log.%a`, `log_truncate_on_rotation` to `on`, and `log_rotation_age` to `1440`.

1. http://pubs.opengroup.org/onlinepubs/009695399/functions/strftime.html

Example: To keep 24 hours of logs, one log file per hour, but also rotate sooner if the log file size exceeds 1GB, set log_filename to server_log.%H%M, log_truncate_on_rotation to on, log_rotation_age to 60, and log_rotation_size to 1000000. Including %M in log_filename allows any size-driven rotations that might occur to select a file name different from the hour's initial file name.

syslog_facility (enum)

When logging to syslog is enabled, this parameter determines the syslog "facility" to be used. You can choose from LOCAL0, LOCAL1, LOCAL2, LOCAL3, LOCAL4, LOCAL5, LOCAL6, LOCAL7; the default is LOCAL0. See also the documentation of your system's syslog daemon. This parameter can only be set in the postgresql.conf file or on the server command line.

syslog_ident (string)

When logging to syslog is enabled, this parameter determines the program name used to identify PostgreSQL messages in syslog logs. The default is postgres. This parameter can only be set in the postgresql.conf file or on the server command line.

event_source (string)

When logging to event log is enabled, this parameter determines the program name used to identify PostgreSQL messages in the log. The default is PostgreSQL. This parameter can only be set in the postgresql.conf file or on the server command line.

18.8.2. When To Log

client_min_messages (enum)

Controls which message levels are sent to the client. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, LOG, NOTICE, WARNING, ERROR, FATAL, and PANIC. Each level includes all the levels that follow it. The later the level, the fewer messages are sent. The default is NOTICE. Note that LOG has a different rank here than in log_min_messages.

log_min_messages (enum)

Controls which message levels are written to the server log. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, ERROR, LOG, FATAL, and PANIC. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log. The default is WARNING. Note that LOG has a different rank here than in client_min_messages. Only superusers can change this setting.

log_min_error_statement (enum)

Controls which SQL statements that cause an error condition are recorded in the server log. The current SQL statement is included in the log entry for any message of the specified severity or higher. Valid values are DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, ERROR, LOG, FATAL, and PANIC. The default is ERROR, which means statements causing errors, log messages, fatal errors, or panics will be logged. To effectively turn off logging of failing statements, set this parameter to PANIC. Only superusers can change this setting.

log_min_duration_statement (integer)

Causes the duration of each completed statement to be logged if the statement ran for at least the specified number of milliseconds. Setting this to zero prints all statement durations. Minus-one (the default) disables logging statement durations. For example, if you set it to 250ms then all SQL statements that run 250ms or longer will be logged. Enabling this parameter can be

helpful in tracking down unoptimized queries in your applications. Only superusers can change this setting.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

> **Note:** When using this option together with log_statement, the text of statements that are logged because of `log_statement` will not be repeated in the duration log message. If you are not using syslog, it is recommended that you log the PID or session ID using log_line_prefix so that you can link the statement message to the later duration message using the process ID or session ID.

Table 18-1 explains the message severity levels used by PostgreSQL. If logging output is sent to syslog or Windows' eventlog, the severity levels are translated as shown in the table.

Table 18-1. Message Severity Levels

Severity	Usage	syslog	eventlog
`DEBUG1..DEBUG5`	Provides successively-more-detailed information for use by developers.	`DEBUG`	`INFORMATION`
`INFO`	Provides information implicitly requested by the user, e.g., output from `VACUUM VERBOSE`.	`INFO`	`INFORMATION`
`NOTICE`	Provides information that might be helpful to users, e.g., notice of truncation of long identifiers.	`NOTICE`	`INFORMATION`
`WARNING`	Provides warnings of likely problems, e.g., `COMMIT` outside a transaction block.	`NOTICE`	`WARNING`
`ERROR`	Reports an error that caused the current command to abort.	`WARNING`	`ERROR`
`LOG`	Reports information of interest to administrators, e.g., checkpoint activity.	`INFO`	`INFORMATION`
`FATAL`	Reports an error that caused the current session to abort.	`ERR`	`ERROR`

Severity	Usage	syslog	eventlog
PANIC	Reports an error that caused all database sessions to abort.	CRIT	ERROR

18.8.3. What To Log

application_name (string)

The application_name can be any string of less than NAMEDATALEN characters (64 characters in a standard build). It is typically set by an application upon connection to the server. The name will be displayed in the pg_stat_activity view and included in CSV log entries. It can also be included in regular log entries via the log_line_prefix parameter. Only printable ASCII characters may be used in the application_name value. Other characters will be replaced with question marks (?).

debug_print_parse (boolean)
debug_print_rewritten (boolean)
debug_print_plan (boolean)

These parameters enable various debugging output to be emitted. When set, they print the resulting parse tree, the query rewriter output, or the execution plan for each executed query. These messages are emitted at LOG message level, so by default they will appear in the server log but will not be sent to the client. You can change that by adjusting client_min_messages and/or log_min_messages. These parameters are off by default.

debug_pretty_print (boolean)

When set, debug_pretty_print indents the messages produced by debug_print_parse, debug_print_rewritten, or debug_print_plan. This results in more readable but much longer output than the "compact" format used when it is off. It is on by default.

log_checkpoints (boolean)

Causes checkpoints and restartpoints to be logged in the server log. Some statistics are included in the log messages, including the number of buffers written and the time spent writing them. This parameter can only be set in the postgresql.conf file or on the server command line. The default is off.

log_connections (boolean)

Causes each attempted connection to the server to be logged, as well as successful completion of client authentication. This parameter cannot be changed after session start. The default is off.

> **Note:** Some client programs, like psql, attempt to connect twice while determining if a password is required, so duplicate "connection received" messages do not necessarily indicate a problem.

log_disconnections (boolean)

This outputs a line in the server log similar to log_connections but at session termination, and includes the duration of the session. This is off by default. This parameter cannot be changed after session start.

log_duration (boolean)

Causes the duration of every completed statement to be logged. The default is off. Only superusers can change this setting.

For clients using extended query protocol, durations of the Parse, Bind, and Execute steps are logged independently.

> **Note:** The difference between setting this option and setting log_min_duration_statement to zero is that exceeding log_min_duration_statement forces the text of the query to be logged, but this option doesn't. Thus, if log_duration is on and log_min_duration_statement has a positive value, all durations are logged but the query text is included only for statements exceeding the threshold. This behavior can be useful for gathering statistics in high-load installations.

log_error_verbosity (enum)

Controls the amount of detail written in the server log for each message that is logged. Valid values are TERSE, DEFAULT, and VERBOSE, each adding more fields to displayed messages. TERSE excludes the logging of DETAIL, HINT, QUERY, and CONTEXT error information. VERBOSE output includes the SQLSTATE error code (see also Appendix A) and the source code file name, function name, and line number that generated the error. Only superusers can change this setting.

log_hostname (boolean)

By default, connection log messages only show the IP address of the connecting host. Turning this parameter on causes logging of the host name as well. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty. This parameter can only be set in the postgresql.conf file or on the server command line.

log_line_prefix (string)

This is a printf-style string that is output at the beginning of each log line. % characters begin "escape sequences" that are replaced with status information as outlined below. Unrecognized escapes are ignored. Other characters are copied straight to the log line. Some escapes are only recognized by session processes, and will be treated as empty by background processes such as the main server process. Status information may be aligned either left or right by specifying a numeric literal after the % and before the option. A negative value will cause the status information to be padded on the right with spaces to give it a minimum width, whereas a positive value will pad on the left. Padding can be useful to aid human readability in log files. This parameter can only be set in the postgresql.conf file or on the server command line. The default is an empty string.

Escape	Effect	Session only
%a	Application name	yes
%u	User name	yes
%d	Database name	yes
%r	Remote host name or IP address, and remote port	yes
%h	Remote host name or IP address	yes
%p	Process ID	no
%t	Time stamp without milliseconds	no

Escape	Effect	Session only
%m	Time stamp with milliseconds	no
%i	Command tag: type of session's current command	yes
%e	SQLSTATE error code	no
%c	Session ID: see below	no
%l	Number of the log line for each session or process, starting at 1	no
%s	Process start time stamp	no
%v	Virtual transaction ID (backendID/localXID)	no
%x	Transaction ID (0 if none is assigned)	no
%q	Produces no output, but tells non-session processes to stop at this point in the string; ignored by session processes	no
%%	Literal %	no

The %c escape prints a quasi-unique session identifier, consisting of two 4-byte hexadecimal numbers (without leading zeros) separated by a dot. The numbers are the process start time and the process ID, so %c can also be used as a space saving way of printing those items. For example, to generate the session identifier from pg_stat_activity, use this query:

```
SELECT to_hex(EXTRACT(EPOCH FROM backend_start)::integer) || '.' ||
       to_hex(pid)
FROM pg_stat_activity;
```

Tip: If you set a nonempty value for log_line_prefix, you should usually make its last character be a space, to provide visual separation from the rest of the log line. A punctuation character can be used too.

Tip: Syslog produces its own time stamp and process ID information, so you probably do not want to include those escapes if you are logging to syslog.

log_lock_waits (boolean)

Controls whether a log message is produced when a session waits longer than deadlock_timeout to acquire a lock. This is useful in determining if lock waits are causing poor performance. The default is off.

log_statement (enum)

Controls which SQL statements are logged. Valid values are none (off), ddl, mod, and all (all statements). ddl logs all data definition statements, such as CREATE, ALTER, and DROP statements. mod logs all ddl statements, plus data-modifying statements such as INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM. PREPARE, EXECUTE, and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type. For clients using extended

query protocol, logging occurs when an Execute message is received, and values of the Bind parameters are included (with any embedded single-quote marks doubled).

The default is `none`. Only superusers can change this setting.

> **Note:** Statements that contain simple syntax errors are not logged even by the `log_statement = all` setting, because the log message is emitted only after basic parsing has been done to determine the statement type. In the case of extended query protocol, this setting likewise does not log statements that fail before the Execute phase (i.e., during parse analysis or planning). Set `log_min_error_statement` to `ERROR` (or lower) to log such statements.

`log_temp_files` (`integer`)

Controls logging of temporary file names and sizes. Temporary files can be created for sorts, hashes, and temporary query results. A log entry is made for each temporary file when it is deleted. A value of zero logs all temporary file information, while positive values log only files whose size is greater than or equal to the specified number of kilobytes. The default setting is -1, which disables such logging. Only superusers can change this setting.

`log_timezone` (`string`)

Sets the time zone used for timestamps written in the server log. Unlike TimeZone, this value is cluster-wide, so that all sessions will report timestamps consistently. The built-in default is `GMT`, but that is typically overridden in `postgresql.conf`; initdb will install a setting there corresponding to its system environment. See Section 8.5.3 for more information. This parameter can only be set in the `postgresql.conf` file or on the server command line.

18.8.4. Using CSV-Format Log Output

Including `csvlog` in the `log_destination` list provides a convenient way to import log files into a database table. This option emits log lines in comma-separated-values (CSV) format, with these columns: time stamp with milliseconds, user name, database name, process ID, client host:port number, session ID, per-session line number, command tag, session start time, virtual transaction ID, regular transaction ID, error severity, SQLSTATE code, error message, error message detail, hint, internal query that led to the error (if any), character count of the error position therein, error context, user query that led to the error (if any and enabled by `log_min_error_statement`), character count of the error position therein, location of the error in the PostgreSQL source code (if `log_error_verbosity` is set to `verbose`), and application name. Here is a sample table definition for storing CSV-format log output:

```
CREATE TABLE postgres_log
(
  log_time timestamp(3) with time zone,
  user_name text,
  database_name text,
  process_id integer,
  connection_from text,
  session_id text,
  session_line_num bigint,
  command_tag text,
  session_start_time timestamp with time zone,
  virtual_transaction_id text,
  transaction_id bigint,
```

```
  error_severity text,
  sql_state_code text,
  message text,
  detail text,
  hint text,
  internal_query text,
  internal_query_pos integer,
  context text,
  query text,
  query_pos integer,
  location text,
  application_name text,
  PRIMARY KEY (session_id, session_line_num)
);
```

To import a log file into this table, use the `COPY FROM` command:

```
COPY postgres_log FROM '/full/path/to/logfile.csv' WITH csv;
```

There are a few things you need to do to simplify importing CSV log files:

1. Set `log_filename` and `log_rotation_age` to provide a consistent, predictable naming scheme for your log files. This lets you predict what the file name will be and know when an individual log file is complete and therefore ready to be imported.
2. Set `log_rotation_size` to 0 to disable size-based log rotation, as it makes the log file name difficult to predict.
3. Set `log_truncate_on_rotation` to `on` so that old log data isn't mixed with the new in the same file.
4. The table definition above includes a primary key specification. This is useful to protect against accidentally importing the same information twice. The `COPY` command commits all of the data it imports at one time, so any error will cause the entire import to fail. If you import a partial log file and later import the file again when it is complete, the primary key violation will cause the import to fail. Wait until the log is complete and closed before importing. This procedure will also protect against accidentally importing a partial line that hasn't been completely written, which would also cause `COPY` to fail.

18.9. Run-time Statistics

18.9.1. Query and Index Statistics Collector

These parameters control server-wide statistics collection features. When statistics collection is enabled, the data that is produced can be accessed via the `pg_stat` and `pg_statio` family of system views. Refer to Chapter 27 for more information.

`track_activities` (`boolean`)

Enables the collection of information on the currently executing command of each session, along with the time when that command began execution. This parameter is on by default. Note that even when enabled, this information is not visible to all users, only to superusers and the user owning the session being reported on, so it should not represent a security risk. Only superusers can change this setting.

`track_activity_query_size` (`integer`)

Specifies the number of bytes reserved to track the currently executing command for each active session, for the `pg_stat_activity.query` field. The default value is 1024. This parameter can only be set at server start.

`track_counts` (`boolean`)

Enables collection of statistics on database activity. This parameter is on by default, because the autovacuum daemon needs the collected information. Only superusers can change this setting.

`track_io_timing` (`boolean`)

Enables timing of database I/O calls. This parameter is off by default, because it will repeatedly query the operating system for the current time, which may cause significant overhead on some platforms. You can use the pg_test_timing tool to measure the overhead of timing on your system. I/O timing information is displayed in pg_stat_database, in the output of EXPLAIN when the `BUFFERS` option is used, and by pg_stat_statements. Only superusers can change this setting.

`track_functions` (`enum`)

Enables tracking of function call counts and time used. Specify `pl` to track only procedural-language functions, `all` to also track SQL and C language functions. The default is `none`, which disables function statistics tracking. Only superusers can change this setting.

> **Note:** SQL-language functions that are simple enough to be "inlined" into the calling query will not be tracked, regardless of this setting.

`update_process_title` (`boolean`)

Enables updating of the process title every time a new SQL command is received by the server. The process title is typically viewed by the `ps` command, or in Windows by using the Process Explorer. Only superusers can change this setting.

`stats_temp_directory` (`string`)

Sets the directory to store temporary statistics data in. This can be a path relative to the data directory or an absolute path. The default is `pg_stat_tmp`. Pointing this at a RAM-based file system will decrease physical I/O requirements and can lead to improved performance. This parameter can only be set in the `postgresql.conf` file or on the server command line.

18.9.2. Statistics Monitoring

`log_statement_stats` (`boolean`)
`log_parser_stats` (`boolean`)
`log_planner_stats` (`boolean`)
`log_executor_stats` (`boolean`)

For each query, output performance statistics of the respective module to the server log. This

is a crude profiling instrument, similar to the Unix `getrusage()` operating system facility. `log_statement_stats` reports total statement statistics, while the others report per-module statistics. `log_statement_stats` cannot be enabled together with any of the per-module options. All of these options are disabled by default. Only superusers can change these settings.

18.10. Automatic Vacuuming

These settings control the behavior of the *autovacuum* feature. Refer to Section 23.1.6 for more information.

`autovacuum` (`boolean`)

Controls whether the server should run the autovacuum launcher daemon. This is on by default; however, track_counts must also be enabled for autovacuum to work. This parameter can only be set in the `postgresql.conf` file or on the server command line.

Note that even when this parameter is disabled, the system will launch autovacuum processes if necessary to prevent transaction ID wraparound. See Section 23.1.5 for more information.

`log_autovacuum_min_duration` (`integer`)

Causes each action executed by autovacuum to be logged if it ran for at least the specified number of milliseconds. Setting this to zero logs all autovacuum actions. Minus-one (the default) disables logging autovacuum actions. For example, if you set this to `250ms` then all automatic vacuums and analyzes that run 250ms or longer will be logged. In addition, when this parameter is set to any value other than `-1`, a message will be logged if an autovacuum action is skipped due to the existence of a conflicting lock. Enabling this parameter can be helpful in tracking autovacuum activity. This setting can only be set in the `postgresql.conf` file or on the server command line.

`autovacuum_max_workers` (`integer`)

Specifies the maximum number of autovacuum processes (other than the autovacuum launcher) which may be running at any one time. The default is three. This parameter can only be set at server start.

`autovacuum_naptime` (`integer`)

Specifies the minimum delay between autovacuum runs on any given database. In each round the daemon examines the database and issues `VACUUM` and `ANALYZE` commands as needed for tables in that database. The delay is measured in seconds, and the default is one minute (`1min`). This parameter can only be set in the `postgresql.conf` file or on the server command line.

`autovacuum_vacuum_threshold` (`integer`)

Specifies the minimum number of updated or deleted tuples needed to trigger a `VACUUM` in any one table. The default is 50 tuples. This parameter can only be set in the `postgresql.conf` file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

`autovacuum_analyze_threshold` (`integer`)

Specifies the minimum number of inserted, updated or deleted tuples needed to trigger an `ANALYZE` in any one table. The default is 50 tuples. This parameter can only be set in the `postgresql.conf` file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

autovacuum_vacuum_scale_factor (floating point)

Specifies a fraction of the table size to add to autovacuum_vacuum_threshold when deciding whether to trigger a VACUUM. The default is 0.2 (20% of table size). This parameter can only be set in the postgresql.conf file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

autovacuum_analyze_scale_factor (floating point)

Specifies a fraction of the table size to add to autovacuum_analyze_threshold when deciding whether to trigger an ANALYZE. The default is 0.1 (10% of table size). This parameter can only be set in the postgresql.conf file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

autovacuum_freeze_max_age (integer)

Specifies the maximum age (in transactions) that a table's pg_class.relfrozenxid field can attain before a VACUUM operation is forced to prevent transaction ID wraparound within the table. Note that the system will launch autovacuum processes to prevent wraparound even when autovacuum is otherwise disabled.

Vacuum also allows removal of old files from the pg_clog subdirectory, which is why the default is a relatively low 200 million transactions. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing storage parameters. For more information see Section 23.1.5.

autovacuum_multixact_freeze_max_age (integer)

Specifies the maximum age (in multixacts) that a table's pg_class.relminmxid field can attain before a VACUUM operation is forced to prevent multixact ID wraparound within the table. Note that the system will launch autovacuum processes to prevent wraparound even when autovacuum is otherwise disabled.

Vacuuming multixacts also allows removal of old files from the pg_multixact/members and pg_multixact/offsets subdirectories, which is why the default is a relatively low 400 million multixacts. This parameter can only be set at server start, but the setting can be reduced for individual tables by changing storage parameters. For more information see Section 23.1.5.1.

autovacuum_vacuum_cost_delay (integer)

Specifies the cost delay value that will be used in automatic VACUUM operations. If -1 is specified, the regular vacuum_cost_delay value will be used. The default value is 20 milliseconds. This parameter can only be set in the postgresql.conf file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

autovacuum_vacuum_cost_limit (integer)

Specifies the cost limit value that will be used in automatic VACUUM operations. If -1 is specified (which is the default), the regular vacuum_cost_limit value will be used. Note that the value is distributed proportionally among the running autovacuum workers, if there is more than one, so that the sum of the limits of each worker never exceeds the limit on this variable. This parameter can only be set in the postgresql.conf file or on the server command line. This setting can be overridden for individual tables by changing storage parameters.

18.11. Client Connection Defaults

18.11.1. Statement Behavior

`search_path` (`string`)

This variable specifies the order in which schemas are searched when an object (table, data type, function, etc.) is referenced by a simple name with no schema specified. When there are objects of identical names in different schemas, the one found first in the search path is used. An object that is not in any of the schemas in the search path can only be referenced by specifying its containing schema with a qualified (dotted) name.

The value for `search_path` must be a comma-separated list of schema names. Any name that is not an existing schema, or is a schema for which the user does not have `USAGE` permission, is silently ignored.

If one of the list items is the special name `$user`, then the schema having the name returned by `SESSION_USER` is substituted, if there is such a schema and the user has `USAGE` permission for it. (If not, `$user` is ignored.)

The system catalog schema, `pg_catalog`, is always searched, whether it is mentioned in the path or not. If it is mentioned in the path then it will be searched in the specified order. If `pg_catalog` is not in the path then it will be searched *before* searching any of the path items.

Likewise, the current session's temporary-table schema, `pg_temp_`*`nnn`*, is always searched if it exists. It can be explicitly listed in the path by using the alias `pg_temp`. If it is not listed in the path then it is searched first (even before `pg_catalog`). However, the temporary schema is only searched for relation (table, view, sequence, etc) and data type names. It is never searched for function or operator names.

When objects are created without specifying a particular target schema, they will be placed in the first valid schema named in `search_path`. An error is reported if the search path is empty.

The default value for this parameter is `"$user", public`. This setting supports shared use of a database (where no users have private schemas, and all share use of `public`), private per-user schemas, and combinations of these. Other effects can be obtained by altering the default search path setting, either globally or per-user.

The current effective value of the search path can be examined via the SQL function `current_schemas` (see Section 9.25). This is not quite the same as examining the value of `search_path`, since `current_schemas` shows how the items appearing in `search_path` were resolved.

For more information on schema handling, see Section 5.7.

`default_tablespace` (`string`)

This variable specifies the default tablespace in which to create objects (tables and indexes) when a `CREATE` command does not explicitly specify a tablespace.

The value is either the name of a tablespace, or an empty string to specify using the default tablespace of the current database. If the value does not match the name of any existing tablespace, PostgreSQL will automatically use the default tablespace of the current database. If a nondefault tablespace is specified, the user must have `CREATE` privilege for it, or creation attempts will fail.

This variable is not used for temporary tables; for them, temp_tablespaces is consulted instead.

This variable is also not used when creating databases. By default, a new database inherits its tablespace setting from the template database it is copied from.

For more information on tablespaces, see Section 21.6.

`temp_tablespaces` (`string`)

This variable specifies tablespaces in which to create temporary objects (temp tables and indexes on temp tables) when a `CREATE` command does not explicitly specify a tablespace. Temporary files for purposes such as sorting large data sets are also created in these tablespaces.

The value is a list of names of tablespaces. When there is more than one name in the list, PostgreSQL chooses a random member of the list each time a temporary object is to be created; except that within a transaction, successively created temporary objects are placed in successive tablespaces from the list. If the selected element of the list is an empty string, PostgreSQL will automatically use the default tablespace of the current database instead.

When `temp_tablespaces` is set interactively, specifying a nonexistent tablespace is an error, as is specifying a tablespace for which the user does not have `CREATE` privilege. However, when using a previously set value, nonexistent tablespaces are ignored, as are tablespaces for which the user lacks `CREATE` privilege. In particular, this rule applies when using a value set in `postgresql.conf`.

The default value is an empty string, which results in all temporary objects being created in the default tablespace of the current database.

See also default_tablespace.

`check_function_bodies` (`boolean`)

This parameter is normally on. When set to `off`, it disables validation of the function body string during CREATE FUNCTION. Disabling validation avoids side effects of the validation process and avoids false positives due to problems such as forward references. Set this parameter to `off` before loading functions on behalf of other users; pg_dump does so automatically.

`default_transaction_isolation` (`enum`)

Each SQL transaction has an isolation level, which can be either “read uncommitted”, “read committed”, “repeatable read”, or “serializable”. This parameter controls the default isolation level of each new transaction. The default is “read committed”.

Consult Chapter 13 and SET TRANSACTION for more information.

`default_transaction_read_only` (`boolean`)

A read-only SQL transaction cannot alter non-temporary tables. This parameter controls the default read-only status of each new transaction. The default is `off` (read/write).

Consult SET TRANSACTION for more information.

`default_transaction_deferrable` (`boolean`)

When running at the `serializable` isolation level, a deferrable read-only SQL transaction may be delayed before it is allowed to proceed. However, once it begins executing it does not incur any of the overhead required to ensure serializability; so serialization code will have no reason to force it to abort because of concurrent updates, making this option suitable for long-running read-only transactions.

This parameter controls the default deferrable status of each new transaction. It currently has no effect on read-write transactions or those operating at isolation levels lower than `serializable`. The default is `off`.

Consult SET TRANSACTION for more information.

session_replication_role (enum)

Controls firing of replication-related triggers and rules for the current session. Setting this variable requires superuser privilege and results in discarding any previously cached query plans. Possible values are origin (the default), replica and local. See ALTER TABLE for more information.

statement_timeout (integer)

Abort any statement that takes more than the specified number of milliseconds, starting from the time the command arrives at the server from the client. If log_min_error_statement is set to ERROR or lower, the statement that timed out will also be logged. A value of zero (the default) turns this off.

Setting statement_timeout in postgresql.conf is not recommended because it would affect all sessions.

lock_timeout (integer)

Abort any statement that waits longer than the specified number of milliseconds while attempting to acquire a lock on a table, index, row, or other database object. The time limit applies separately to each lock acquisition attempt. The limit applies both to explicit locking requests (such as LOCK TABLE, or SELECT FOR UPDATE without NOWAIT) and to implicitly-acquired locks. If log_min_error_statement is set to ERROR or lower, the statement that timed out will be logged. A value of zero (the default) turns this off.

Unlike statement_timeout, this timeout can only occur while waiting for locks. Note that if statement_timeout is nonzero, it is rather pointless to set lock_timeout to the same or larger value, since the statement timeout would always trigger first.

Setting lock_timeout in postgresql.conf is not recommended because it would affect all sessions.

vacuum_freeze_table_age (integer)

VACUUM performs a whole-table scan if the table's pg_class.relfrozenxid field has reached the age specified by this setting. The default is 150 million transactions. Although users can set this value anywhere from zero to two billions, VACUUM will silently limit the effective value to 95% of autovacuum_freeze_max_age, so that a periodical manual VACUUM has a chance to run before an anti-wraparound autovacuum is launched for the table. For more information see Section 23.1.5.

vacuum_freeze_min_age (integer)

Specifies the cutoff age (in transactions) that VACUUM should use to decide whether to freeze row versions while scanning a table. The default is 50 million transactions. Although users can set this value anywhere from zero to one billion, VACUUM will silently limit the effective value to half the value of autovacuum_freeze_max_age, so that there is not an unreasonably short time between forced autovacuums. For more information see Section 23.1.5.

vacuum_multixact_freeze_table_age (integer)

VACUUM performs a whole-table scan if the table's pg_class.relminmxid field has reached the age specified by this setting. The default is 150 million multixacts. Although users can set this value anywhere from zero to two billions, VACUUM will silently limit the effective value to 95% of autovacuum_multixact_freeze_max_age, so that a periodical manual VACUUM has a chance to run before an anti-wraparound is launched for the table. For more information see Section 23.1.5.1.

vacuum_multixact_freeze_min_age (integer)

Specifies the cutoff age (in multixacts) that VACUUM should use to decide whether to replace multixact IDs with a newer transaction ID or multixact ID while scanning a table. The default is 5 million multixacts. Although users can set this value anywhere from zero to one billion, VACUUM will silently limit the effective value to half the value of autovacuum_multixact_freeze_max_age, so that there is not an unreasonably short time between forced autovacuums. For more information see Section 23.1.5.1.

bytea_output (enum)

Sets the output format for values of type bytea. Valid values are hex (the default) and escape (the traditional PostgreSQL format). See Section 8.4 for more information. The bytea type always accepts both formats on input, regardless of this setting.

xmlbinary (enum)

Sets how binary values are to be encoded in XML. This applies for example when bytea values are converted to XML by the functions xmlelement or xmlforest. Possible values are base64 and hex, which are both defined in the XML Schema standard. The default is base64. For further information about XML-related functions, see Section 9.14.

The actual choice here is mostly a matter of taste, constrained only by possible restrictions in client applications. Both methods support all possible values, although the hex encoding will be somewhat larger than the base64 encoding.

xmloption (enum)

Sets whether DOCUMENT or CONTENT is implicit when converting between XML and character string values. See Section 8.13 for a description of this. Valid values are DOCUMENT and CONTENT. The default is CONTENT.

According to the SQL standard, the command to set this option is

```
SET XML OPTION { DOCUMENT | CONTENT };
```

This syntax is also available in PostgreSQL.

18.11.2. Locale and Formatting

DateStyle (string)

Sets the display format for date and time values, as well as the rules for interpreting ambiguous date input values. For historical reasons, this variable contains two independent components: the output format specification (ISO, Postgres, SQL, or German) and the input/output specification for year/month/day ordering (DMY, MDY, or YMD). These can be set separately or together. The keywords Euro and European are synonyms for DMY; the keywords US, NonEuro, and NonEuropean are synonyms for MDY. See Section 8.5 for more information. The built-in default is ISO, MDY, but initdb will initialize the configuration file with a setting that corresponds to the behavior of the chosen lc_time locale.

IntervalStyle (enum)

Sets the display format for interval values. The value sql_standard will produce output matching SQL standard interval literals. The value postgres (which is the default) will produce output matching PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to ISO. The value postgres_verbose will produce output matching PostgreSQL releases prior to 8.4 when the DateStyle parameter was set to non-ISO output. The value iso_8601 will produce

output matching the time interval "format with designators" defined in section 4.4.3.2 of ISO 8601.

The `IntervalStyle` parameter also affects the interpretation of ambiguous interval input. See Section 8.5.4 for more information.

`TimeZone` (`string`)

Sets the time zone for displaying and interpreting time stamps. The built-in default is `GMT`, but that is typically overridden in `postgresql.conf`; initdb will install a setting there corresponding to its system environment. See Section 8.5.3 for more information.

`timezone_abbreviations` (`string`)

Sets the collection of time zone abbreviations that will be accepted by the server for datetime input. The default is `'Default'`, which is a collection that works in most of the world; there are also `'Australia'` and `'India'`, and other collections can be defined for a particular installation. See Section B.3 for more information.

`extra_float_digits` (`integer`)

This parameter adjusts the number of digits displayed for floating-point values, including `float4`, `float8`, and geometric data types. The parameter value is added to the standard number of digits (`FLT_DIG` or `DBL_DIG` as appropriate). The value can be set as high as 3, to include partially-significant digits; this is especially useful for dumping float data that needs to be restored exactly. Or it can be set negative to suppress unwanted digits. See also Section 8.1.3.

`client_encoding` (`string`)

Sets the client-side encoding (character set). The default is to use the database encoding. The character sets supported by the PostgreSQL server are described in Section 22.3.1.

`lc_messages` (`string`)

Sets the language in which messages are displayed. Acceptable values are system-dependent; see Section 22.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

On some systems, this locale category does not exist. Setting this variable will still work, but there will be no effect. Also, there is a chance that no translated messages for the desired language exist. In that case you will continue to see the English messages.

Only superusers can change this setting, because it affects the messages sent to the server log as well as to the client, and an improper value might obscure the readability of the server logs.

`lc_monetary` (`string`)

Sets the locale to use for formatting monetary amounts, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 22.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

`lc_numeric` (`string`)

Sets the locale to use for formatting numbers, for example with the `to_char` family of functions. Acceptable values are system-dependent; see Section 22.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

lc_time (string)

Sets the locale to use for formatting dates and times, for example with the to_char family of functions. Acceptable values are system-dependent; see Section 22.1 for more information. If this variable is set to the empty string (which is the default) then the value is inherited from the execution environment of the server in a system-dependent way.

default_text_search_config (string)

Selects the text search configuration that is used by those variants of the text search functions that do not have an explicit argument specifying the configuration. See Chapter 12 for further information. The built-in default is pg_catalog.simple, but initdb will initialize the configuration file with a setting that corresponds to the chosen lc_ctype locale, if a configuration matching that locale can be identified.

18.11.3. Shared Library Preloading

Several settings are available for preloading shared libraries into the server, in order to load additional functionality or achieve performance benefits. For example, a setting of '$libdir/mylib' would cause mylib.so (or on some platforms, mylib.sl) to be preloaded from the installation's standard library directory. The differences between the settings are when they take effect and what privileges are required to change them.

PostgreSQL procedural language libraries can be preloaded in this way, typically by using the syntax '$libdir/plXXX' where XXX is pgsql, perl, tcl, or python.

For each parameter, if more than one library is to be loaded, separate their names with commas. All library names are converted to lower case unless double-quoted.

Only shared libraries specifically intended to be used with PostgreSQL can be loaded this way. Every PostgreSQL-supported library has a "magic block" that is checked to guarantee compatibility. For this reason, non-PostgreSQL libraries cannot be loaded in this way. You might be able to use operating-system facilities such as LD_PRELOAD for that.

In general, refer to the documentation of a specific module for the recommended way to load that module.

local_preload_libraries (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. This parameter cannot be changed after the start of a particular session. If a specified library is not found, the connection attempt will fail.

This option can be set by any user. Because of that, the libraries that can be loaded are restricted to those appearing in the plugins subdirectory of the installation's standard library directory. (It is the database administrator's responsibility to ensure that only "safe" libraries are installed there.) Entries in local_preload_libraries can specify this directory explicitly, for example $libdir/plugins/mylib, or just specify the library name — mylib would have the same effect as $libdir/plugins/mylib.

Unless a module is specifically designed to be used in this way by non-superusers, this is usually not the right setting to use. Look at session_preload_libraries instead.

session_preload_libraries (string)

This variable specifies one or more shared libraries that are to be preloaded at connection start. Only superusers can change this setting. The parameter value only takes effect at the start of the

connection. Subsequent changes have no effect. If a specified library is not found, the connection attempt will fail.

The intent of this feature is to allow debugging or performance-measurement libraries to be loaded into specific sessions without an explicit `LOAD` command being given. For example, auto_explain could be enabled for all sessions under a given user name by setting this parameter with `ALTER ROLE SET`. Also, this parameter can be changed without restarting the server (but changes only take effect when a new session is started), so it is easier to add new modules this way, even if they should apply to all sessions.

Unlike shared_preload_libraries, there is no large performance advantage to loading a library at session start rather than when it is first used. There is some advantage, however, when connection pooling is used.

`shared_preload_libraries` (`string`)

This variable specifies one or more shared libraries to be preloaded at server start. with commas. This parameter can only be set at server start. If a specified library is not found, the server will fail to start.

Some libraries need to perform certain operations that can only take place at postmaster start, such as allocating shared memory, reserving light-weight locks, or starting background workers. Those libraries must be loaded at server start through this parameter. See the documentation of each library for details.

Other libraries can also be preloaded. By preloading a shared library, the library startup time is avoided when the library is first used. However, the time to start each new server process might increase slightly, even if that process never uses the library. So this parameter is recommended only for libraries that will be used in most sessions. Also, changing this parameter requires a server restart, so this is not the right setting to use for short-term debugging tasks, say. Use session_preload_libraries for that instead.

> **Note:** On Windows hosts, preloading a library at server start will not reduce the time required to start each new server process; each server process will re-load all preload libraries. However, `shared_preload_libraries` is still useful on Windows hosts for libraries that need to perform operations at postmaster start time.

18.11.4. Other Defaults

`dynamic_library_path` (`string`)

If a dynamically loadable module needs to be opened and the file name specified in the `CREATE FUNCTION` or `LOAD` command does not have a directory component (i.e., the name does not contain a slash), the system will search this path for the required file.

The value for `dynamic_library_path` must be a list of absolute directory paths separated by colons (or semi-colons on Windows). If a list element starts with the special string `$libdir`, the compiled-in PostgreSQL package library directory is substituted for `$libdir`; this is where the modules provided by the standard PostgreSQL distribution are installed. (Use `pg_config --pkglibdir` to find out the name of this directory.) For example:

```
dynamic_library_path = '/usr/local/lib/postgresql:/home/my_project/lib:$libdir'
```

or, in a Windows environment:

```
dynamic_library_path = 'C:\tools\postgresql;H:\my_project\lib;$libdir'
```

The default value for this parameter is `'$libdir'`. If the value is set to an empty string, the automatic path search is turned off.

This parameter can be changed at run time by superusers, but a setting done that way will only persist until the end of the client connection, so this method should be reserved for development purposes. The recommended way to set this parameter is in the `postgresql.conf` configuration file.

`gin_fuzzy_search_limit` (`integer`)

Soft upper limit of the size of the set returned by GIN index scans. For more information see Section 58.5.

18.12. Lock Management

`deadlock_timeout` (`integer`)

This is the amount of time, in milliseconds, to wait on a lock before checking to see if there is a deadlock condition. The check for deadlock is relatively expensive, so the server doesn't run it every time it waits for a lock. We optimistically assume that deadlocks are not common in production applications and just wait on the lock for a while before checking for a deadlock. Increasing this value reduces the amount of time wasted in needless deadlock checks, but slows down reporting of real deadlock errors. The default is one second (`1s`), which is probably about the smallest value you would want in practice. On a heavily loaded server you might want to raise it. Ideally the setting should exceed your typical transaction time, so as to improve the odds that a lock will be released before the waiter decides to check for deadlock. Only superusers can change this setting.

When log_lock_waits is set, this parameter also determines the length of time to wait before a log message is issued about the lock wait. If you are trying to investigate locking delays you might want to set a shorter than normal `deadlock_timeout`.

`max_locks_per_transaction` (`integer`)

The shared lock table tracks locks on `max_locks_per_transaction` * (max_connections + max_prepared_transactions) objects (e.g., tables); hence, no more than this many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of rows that can be locked; that value is unlimited. The default, 64, has historically proven sufficient, but you might need to raise this value if you have queries that touch many different tables in a single transaction, e.g. query of a parent table with many children. This parameter can only be set at server start.

When running a standby server, you must set this parameter to the same or higher value than on the master server. Otherwise, queries will not be allowed in the standby server.

`max_pred_locks_per_transaction` (`integer`)

The shared predicate lock table tracks locks on `max_pred_locks_per_transaction` * (max_connections + max_prepared_transactions) objects (e.g., tables); hence, no more than this many distinct objects can be locked at any one time. This parameter controls the average number of object locks allocated for each transaction; individual transactions can lock more objects as long as the locks of all transactions fit in the lock table. This is *not* the number of

rows that can be locked; that value is unlimited. The default, 64, has generally been sufficient in testing, but you might need to raise this value if you have clients that touch many different tables in a single serializable transaction. This parameter can only be set at server start.

18.13. Version and Platform Compatibility

18.13.1. Previous PostgreSQL Versions

`array_nulls` (`boolean`)

This controls whether the array input parser recognizes unquoted `NULL` as specifying a null array element. By default, this is `on`, allowing array values containing null values to be entered. However, PostgreSQL versions before 8.2 did not support null values in arrays, and therefore would treat `NULL` as specifying a normal array element with the string value "NULL". For backward compatibility with applications that require the old behavior, this variable can be turned `off`.

Note that it is possible to create array values containing null values even when this variable is `off`.

`backslash_quote` (`enum`)

This controls whether a quote mark can be represented by `\'` in a string literal. The preferred, SQL-standard way to represent a quote mark is by doubling it (`''`) but PostgreSQL has historically also accepted `\'`. However, use of `\'` creates security risks because in some client character set encodings, there are multibyte characters in which the last byte is numerically equivalent to ASCII `\`. If client-side code does escaping incorrectly then a SQL-injection attack is possible. This risk can be prevented by making the server reject queries in which a quote mark appears to be escaped by a backslash. The allowed values of `backslash_quote` are `on` (allow `\'` always), `off` (reject always), and `safe_encoding` (allow only if client encoding does not allow ASCII `\` within a multibyte character). `safe_encoding` is the default setting.

Note that in a standard-conforming string literal, `\` just means `\` anyway. This parameter only affects the handling of non-standard-conforming literals, including escape string syntax (`E'...'`).

`default_with_oids` (`boolean`)

This controls whether `CREATE TABLE` and `CREATE TABLE AS` include an OID column in newly-created tables, if neither `WITH OIDS` nor `WITHOUT OIDS` is specified. It also determines whether OIDs will be included in tables created by `SELECT INTO`. The parameter is `off` by default; in PostgreSQL 8.0 and earlier, it was on by default.

The use of OIDs in user tables is considered deprecated, so most installations should leave this variable disabled. Applications that require OIDs for a particular table should specify `WITH OIDS` when creating the table. This variable can be enabled for compatibility with old applications that do not follow this behavior.

`escape_string_warning` (`boolean`)

When on, a warning is issued if a backslash (`\`) appears in an ordinary string literal (`'...'` syntax) and `standard_conforming_strings` is off. The default is `on`.

Applications that wish to use backslash as escape should be modified to use escape string syntax (`E'...'`), because the default behavior of ordinary strings is now to treat backslash as an ordinary character, per SQL standard. This variable can be enabled to help locate code that needs to be changed.

lo_compat_privileges (boolean)

In PostgreSQL releases prior to 9.0, large objects did not have access privileges and were, therefore, always readable and writable by all users. Setting this variable to on disables the new privilege checks, for compatibility with prior releases. The default is off. Only superusers can change this setting.

Setting this variable does not disable all security checks related to large objects — only those for which the default behavior has changed in PostgreSQL 9.0. For example, lo_import() and lo_export() need superuser privileges regardless of this setting.

quote_all_identifiers (boolean)

When the database generates SQL, force all identifiers to be quoted, even if they are not (currently) keywords. This will affect the output of EXPLAIN as well as the results of functions like pg_get_viewdef. See also the --quote-all-identifiers option of pg_dump and pg_dumpall.

sql_inheritance (boolean)

This setting controls whether undecorated table references are considered to include inheritance child tables. The default is on, which means child tables are included (thus, a * suffix is assumed by default). If turned off, child tables are not included (thus, an ONLY prefix is assumed). The SQL standard requires child tables to be included, so the off setting is not spec-compliant, but it is provided for compatibility with PostgreSQL releases prior to 7.1. See Section 5.8 for more information.

Turning sql_inheritance off is deprecated, because that behavior has been found to be error-prone as well as contrary to SQL standard. Discussions of inheritance behavior elsewhere in this manual generally assume that it is on.

standard_conforming_strings (boolean)

This controls whether ordinary string literals ('...') treat backslashes literally, as specified in the SQL standard. Beginning in PostgreSQL 9.1, the default is on (prior releases defaulted to off). Applications can check this parameter to determine how string literals will be processed. The presence of this parameter can also be taken as an indication that the escape string syntax (E'...') is supported. Escape string syntax (Section 4.1.2.2) should be used if an application desires backslashes to be treated as escape characters.

synchronize_seqscans (boolean)

This allows sequential scans of large tables to synchronize with each other, so that concurrent scans read the same block at about the same time and hence share the I/O workload. When this is enabled, a scan might start in the middle of the table and then "wrap around" the end to cover all rows, so as to synchronize with the activity of scans already in progress. This can result in unpredictable changes in the row ordering returned by queries that have no ORDER BY clause. Setting this parameter to off ensures the pre-8.3 behavior in which a sequential scan always starts from the beginning of the table. The default is on.

18.13.2. Platform and Client Compatibility

transform_null_equals (boolean)

When on, expressions of the form *expr* = NULL (or NULL = *expr*) are treated as *expr* IS NULL, that is, they return true if *expr* evaluates to the null value, and false otherwise. The correct

SQL-spec-compliant behavior of *expr* = NULL is to always return null (unknown). Therefore this parameter defaults to off.

However, filtered forms in Microsoft Access generate queries that appear to use *expr* = NULL to test for null values, so if you use that interface to access the database you might want to turn this option on. Since expressions of the form *expr* = NULL always return the null value (using the SQL standard interpretation), they are not very useful and do not appear often in normal applications so this option does little harm in practice. But new users are frequently confused about the semantics of expressions involving null values, so this option is off by default.

Note that this option only affects the exact form = NULL, not other comparison operators or other expressions that are computationally equivalent to some expression involving the equals operator (such as IN). Thus, this option is not a general fix for bad programming.

Refer to Section 9.2 for related information.

18.14. Error Handling

exit_on_error (boolean)

If true, any error will terminate the current session. By default, this is set to false, so that only FATAL errors will terminate the session.

restart_after_crash (boolean)

When set to true, which is the default, PostgreSQL will automatically reinitialize after a backend crash. Leaving this value set to true is normally the best way to maximize the availability of the database. However, in some circumstances, such as when PostgreSQL is being invoked by clusterware, it may be useful to disable the restart so that the clusterware can gain control and take any actions it deems appropriate.

18.15. Preset Options

The following "parameters" are read-only, and are determined when PostgreSQL is compiled or when it is installed. As such, they have been excluded from the sample postgresql.conf file. These options report various aspects of PostgreSQL behavior that might be of interest to certain applications, particularly administrative front-ends.

block_size (integer)

Reports the size of a disk block. It is determined by the value of BLCKSZ when building the server. The default value is 8192 bytes. The meaning of some configuration variables (such as shared_buffers) is influenced by block_size. See Section 18.4 for information.

data_checksums (boolean)

Reports whether data checksums are enabled for this cluster. See data checksums for more information.

integer_datetimes (boolean)

Reports whether PostgreSQL was built with support for 64-bit-integer dates and times. This can be disabled by configuring with --disable-integer-datetimes when building PostgreSQL. The default value is on.

`lc_collate` (`string`)

Reports the locale in which sorting of textual data is done. See Section 22.1 for more information. This value is determined when a database is created.

`lc_ctype` (`string`)

Reports the locale that determines character classifications. See Section 22.1 for more information. This value is determined when a database is created. Ordinarily this will be the same as `lc_collate`, but for special applications it might be set differently.

`max_function_args` (`integer`)

Reports the maximum number of function arguments. It is determined by the value of `FUNC_MAX_ARGS` when building the server. The default value is 100 arguments.

`max_identifier_length` (`integer`)

Reports the maximum identifier length. It is determined as one less than the value of `NAMEDATALEN` when building the server. The default value of `NAMEDATALEN` is 64; therefore the default `max_identifier_length` is 63 bytes, which can be less than 63 characters when using multibyte encodings.

`max_index_keys` (`integer`)

Reports the maximum number of index keys. It is determined by the value of `INDEX_MAX_KEYS` when building the server. The default value is 32 keys.

`segment_size` (`integer`)

Reports the number of blocks (pages) that can be stored within a file segment. It is determined by the value of `RELSEG_SIZE` when building the server. The maximum size of a segment file in bytes is equal to `segment_size` multiplied by `block_size`; by default this is 1GB.

`server_encoding` (`string`)

Reports the database encoding (character set). It is determined when the database is created. Ordinarily, clients need only be concerned with the value of client_encoding.

`server_version` (`string`)

Reports the version number of the server. It is determined by the value of `PG_VERSION` when building the server.

`server_version_num` (`integer`)

Reports the version number of the server as an integer. It is determined by the value of `PG_VERSION_NUM` when building the server.

`wal_block_size` (`integer`)

Reports the size of a WAL disk block. It is determined by the value of `XLOG_BLCKSZ` when building the server. The default value is 8192 bytes.

`wal_segment_size` (`integer`)

Reports the number of blocks (pages) in a WAL segment file. The total size of a WAL segment file in bytes is equal to `wal_segment_size` multiplied by `wal_block_size`; by default this is 16MB. See Section 29.4 for more information.

18.16. Customized Options

This feature was designed to allow parameters not normally known to PostgreSQL to be added by add-on modules (such as procedural languages). This allows extension modules to be configured in the standard ways.

Custom options have two-part names: an extension name, then a dot, then the parameter name proper, much like qualified names in SQL. An example is `plpgsql.variable_conflict`.

Because custom options may need to be set in processes that have not loaded the relevant extension module, PostgreSQL will accept a setting for any two-part parameter name. Such variables are treated as placeholders and have no function until the module that defines them is loaded. When an extension module is loaded, it will add its variable definitions, convert any placeholder values according to those definitions, and issue warnings for any unrecognized placeholders that begin with its extension name.

18.17. Developer Options

The following parameters are intended for work on the PostgreSQL source code, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them on a production database. As such, they have been excluded from the sample `postgresql.conf` file. Note that many of these parameters require special source compilation flags to work at all.

`allow_system_table_mods` (`boolean`)

Allows modification of the structure of system tables. This is used by `initdb`. This parameter can only be set at server start.

`debug_assertions` (`boolean`)

Turns on various assertion checks. This is a debugging aid. If you are experiencing strange problems or crashes you might want to turn this on, as it might expose programming mistakes. To use this parameter, the macro `USE_ASSERT_CHECKING` must be defined when PostgreSQL is built (accomplished by the `configure` option `--enable-cassert`). Note that `debug_assertions` defaults to `on` if PostgreSQL has been built with assertions enabled.

`ignore_system_indexes` (`boolean`)

Ignore system indexes when reading system tables (but still update the indexes when modifying the tables). This is useful when recovering from damaged system indexes. This parameter cannot be changed after session start.

`post_auth_delay` (`integer`)

If nonzero, a delay of this many seconds occurs when a new server process is started, after it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger. This parameter cannot be changed after session start.

`pre_auth_delay` (`integer`)

If nonzero, a delay of this many seconds occurs just after a new server process is forked, before it conducts the authentication procedure. This is intended to give developers an opportunity to attach to the server process with a debugger to trace down misbehavior in authentication. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`trace_notify` (`boolean`)

Generates a great amount of debugging output for the `LISTEN` and `NOTIFY` commands. client_min_messages or log_min_messages must be `DEBUG1` or lower to send this output to the client or server logs, respectively.

`trace_recovery_messages` (`enum`)

Enables logging of recovery-related debugging output that otherwise would not be logged. This parameter allows the user to override the normal setting of log_min_messages, but only for specific messages. This is intended for use in debugging Hot Standby. Valid values are `DEBUG5`, `DEBUG4`, `DEBUG3`, `DEBUG2`, `DEBUG1`, and `LOG`. The default, `LOG`, does not affect logging decisions at all. The other values cause recovery-related debug messages of that priority or higher to be logged as though they had `LOG` priority; for common settings of `log_min_messages` this results in unconditionally sending them to the server log. This parameter can only be set in the `postgresql.conf` file or on the server command line.

`trace_sort` (`boolean`)

If on, emit information about resource usage during sort operations. This parameter is only available if the `TRACE_SORT` macro was defined when PostgreSQL was compiled. (However, `TRACE_SORT` is currently defined by default.)

`trace_locks` (`boolean`)

If on, emit information about lock usage. Information dumped includes the type of lock operation, the type of lock and the unique identifier of the object being locked or unlocked. Also included are bit masks for the lock types already granted on this object as well as for the lock types awaited on this object. For each lock type a count of the number of granted locks and waiting locks is also dumped as well as the totals. An example of the log file output is shown here:

```
LOG:  LockAcquire: new: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG:  GrantLock: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(2) req(1,0,0,0,0,0,0)=1 grant(1,0,0,0,0,0,0)=1
      wait(0) type(AccessShareLock)
LOG:  UnGrantLock: updated: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0)=0
      wait(0) type(AccessShareLock)
LOG:  CleanUpLock: deleting: lock(0xb7acd844) id(24688,24696,0,0,0,1)
      grantMask(0) req(0,0,0,0,0,0,0)=0 grant(0,0,0,0,0,0,0)=0
      wait(0) type(INVALID)
```

Details of the structure being dumped may be found in `src/include/storage/lock.h`.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_lwlocks` (`boolean`)

If on, emit information about lightweight lock usage. Lightweight locks are intended primarily to provide mutual exclusion of access to shared-memory data structures.

This parameter is only available if the `LOCK_DEBUG` macro was defined when PostgreSQL was compiled.

`trace_userlocks` (`boolean`)

If on, emit information about user lock usage. Output is the same as for `trace_locks`, only for advisory locks.

This parameter is only available if the LOCK_DEBUG macro was defined when PostgreSQL was compiled.

trace_lock_oidmin (integer)

If set, do not trace locks for tables below this OID. (use to avoid output on system tables)

This parameter is only available if the LOCK_DEBUG macro was defined when PostgreSQL was compiled.

trace_lock_table (integer)

Unconditionally trace locks on this table (OID).

This parameter is only available if the LOCK_DEBUG macro was defined when PostgreSQL was compiled.

debug_deadlocks (boolean)

If set, dumps information about all current locks when a deadlock timeout occurs.

This parameter is only available if the LOCK_DEBUG macro was defined when PostgreSQL was compiled.

log_btree_build_stats (boolean)

If set, logs system resource usage statistics (memory and CPU) on various B-tree operations.

This parameter is only available if the BTREE_BUILD_STATS macro was defined when PostgreSQL was compiled.

wal_debug (boolean)

If on, emit WAL-related debugging output. This parameter is only available if the WAL_DEBUG macro was defined when PostgreSQL was compiled.

ignore_checksum_failure (boolean)

Only has effect if data checksums are enabled.

Detection of a checksum failure during a read normally causes PostgreSQL to report an error, aborting the current transaction. Setting ignore_checksum_failure to on causes the system to ignore the failure (but still report a warning), and continue processing. This behavior may *cause crashes, propagate or hide corruption, or other serious problems*. However, it may allow you to get past the error and retrieve undamaged tuples that might still be present in the table if the block header is still sane. If the header is corrupt an error will be reported even if this option is enabled. The default setting is off, and it can only be changed by a superuser.

zero_damaged_pages (boolean)

Detection of a damaged page header normally causes PostgreSQL to report an error, aborting the current transaction. Setting zero_damaged_pages to on causes the system to instead report a warning, zero out the damaged page in memory, and continue processing. This behavior *will destroy data*, namely all the rows on the damaged page. However, it does allow you to get past the error and retrieve rows from any undamaged pages that might be present in the table. It is useful for recovering data if corruption has occurred due to a hardware or software error. You should generally not set this on until you have given up hope of recovering data from the damaged pages of a table. Zeroed-out pages are not forced to disk so it is recommended to recreate the table or the index before turning this parameter off again. The default setting is off, and it can only be changed by a superuser.

18.18. Short Options

For convenience there are also single letter command-line option switches available for some parameters. They are described in Table 18-2. Some of these options exist for historical reasons, and their presence as a single-letter option does not necessarily indicate an endorsement to use the option heavily.

Table 18-2. Short Option Key

Short Option	Equivalent
-A *x*	debug_assertions = *x*
-B *x*	shared_buffers = *x*
-d *x*	log_min_messages = DEBUG*x*
-e	datestyle = euro
-fb, -fh, -fi, -fm, -fn, -fo, -fs, -ft	enable_bitmapscan = off, enable_hashjoin = off, enable_indexscan = off, enable_mergejoin = off, enable_nestloop = off, enable_indexonlyscan = off, enable_seqscan = off, enable_tidscan = off
-F	fsync = off
-h *x*	listen_addresses = *x*
-i	listen_addresses = '*'
-k *x*	unix_socket_directories = *x*
-l	ssl = on
-N *x*	max_connections = *x*
-O	allow_system_table_mods = on
-p *x*	port = *x*
-P	ignore_system_indexes = on
-s	log_statement_stats = on
-S *x*	work_mem = *x*
-tpa, -tpl, -te	log_parser_stats = on, log_planner_stats = on, log_executor_stats = on
-W *x*	post_auth_delay = *x*

Chapter 19. Client Authentication

When a client application connects to the database server, it specifies which PostgreSQL database user name it wants to connect as, much the same way one logs into a Unix computer as a particular user. Within the SQL environment the active database user name determines access privileges to database objects — see Chapter 20 for more information. Therefore, it is essential to restrict which database users can connect.

> **Note:** As explained in Chapter 20, PostgreSQL actually does privilege management in terms of "roles". In this chapter, we consistently use *database user* to mean "role with the `LOGIN` privilege".

Authentication is the process by which the database server establishes the identity of the client, and by extension determines whether the client application (or the user who runs the client application) is permitted to connect with the database user name that was requested.

PostgreSQL offers a number of different client authentication methods. The method used to authenticate a particular client connection can be selected on the basis of (client) host address, database, and user.

PostgreSQL database user names are logically separate from user names of the operating system in which the server runs. If all the users of a particular server also have accounts on the server's machine, it makes sense to assign database user names that match their operating system user names. However, a server that accepts remote connections might have many database users who have no local operating system account, and in such cases there need be no connection between database user names and OS user names.

19.1. The `pg_hba.conf` File

Client authentication is controlled by a configuration file, which traditionally is named `pg_hba.conf` and is stored in the database cluster's data directory. (HBA stands for host-based authentication.) A default `pg_hba.conf` file is installed when the data directory is initialized by `initdb`. It is possible to place the authentication configuration file elsewhere, however; see the hba_file configuration parameter.

The general format of the `pg_hba.conf` file is a set of records, one per line. Blank lines are ignored, as is any text after the `#` comment character. Records cannot be continued across lines. A record is made up of a number of fields which are separated by spaces and/or tabs. Fields can contain white space if the field value is double-quoted. Quoting one of the keywords in a database, user, or address field (e.g., `all` or `replication`) makes the word lose its special meaning, and just match a database, user, or host with that name.

Each record specifies a connection type, a client IP address range (if relevant for the connection type), a database name, a user name, and the authentication method to be used for connections matching these parameters. The first record with a matching connection type, client address, requested database, and user name is used to perform authentication. There is no "fall-through" or "backup": if one record is chosen and the authentication fails, subsequent records are not considered. If no record matches, access is denied.

A record can have one of the seven formats

```
local      database  user  auth-method  [auth-options]
host       database  user  address  auth-method  [auth-options]
```

```
hostssl     database  user  address  auth-method  [auth-options]
hostnossl   database  user  address  auth-method  [auth-options]
host        database  user  IP-address  IP-mask  auth-method  [auth-options]
hostssl     database  user  IP-address  IP-mask  auth-method  [auth-options]
hostnossl   database  user  IP-address  IP-mask  auth-method  [auth-options]
```

The meaning of the fields is as follows:

`local`

This record matches connection attempts using Unix-domain sockets. Without a record of this type, Unix-domain socket connections are disallowed.

`host`

This record matches connection attempts made using TCP/IP. `host` records match either SSL or non-SSL connection attempts.

> **Note:** Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the listen_addresses configuration parameter, since the default behavior is to listen for TCP/IP connections only on the local loopback address `localhost`.

`hostssl`

This record matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption.

To make use of this option the server must be built with SSL support. Furthermore, SSL must be enabled at server start time by setting the ssl configuration parameter (see Section 17.9 for more information).

`hostnossl`

This record type has the opposite behavior of `hostssl`; it only matches connection attempts made over TCP/IP that do not use SSL.

`database`

Specifies which database name(s) this record matches. The value `all` specifies that it matches all databases. The value `sameuser` specifies that the record matches if the requested database has the same name as the requested user. The value `samerole` specifies that the requested user must be a member of the role with the same name as the requested database. (`samegroup` is an obsolete but still accepted spelling of `samerole`.) Superusers are not considered to be members of a role for the purposes of `samerole` unless they are explicitly members of the role, directly or indirectly, and not just by virtue of being a superuser. The value `replication` specifies that the record matches if a replication connection is requested (note that replication connections do not specify any particular database). Otherwise, this is the name of a specific PostgreSQL database. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with `@`.

`user`

Specifies which database user name(s) this record matches. The value `all` specifies that it matches all users. Otherwise, this is either the name of a specific database user, or a group name preceded by +. (Recall that there is no real distinction between users and groups in PostgreSQL; a + mark really means “match any of the roles that are directly or indirectly members of this role”, while a name without a + mark matches only that specific role.) For this purpose, a

superuser is only considered to be a member of a role if they are explicitly a member of the role, directly or indirectly, and not just by virtue of being a superuser. Multiple user names can be supplied by separating them with commas. A separate file containing user names can be specified by preceding the file name with `@`.

address

Specifies the client machine addresses that this record matches. This field can contain either a host name, an IP address range, or one of the special key words mentioned below.

An IP address is specified in standard dotted decimal notation with a CIDR mask length. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this should be zero in the given IP address. There must not be any white space between the IP address, the `/`, and the CIDR mask length.

Typical examples of an IP address range specified this way are `172.20.143.89/32` for a single host, or `172.20.143.0/24` for a small network, or `10.6.0.0/16` for a larger one. `0.0.0.0/0` represents all IPv4 addresses, and `::/0` represents all IPv6 addresses. To specify a single host, use a CIDR mask of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.

An IP address given in IPv4 format will match IPv6 connections that have the corresponding address, for example `127.0.0.1` will match the IPv6 address `::ffff:127.0.0.1`. An entry given in IPv6 format will match only IPv6 connections, even if the represented address is in the IPv4-in-IPv6 range. Note that entries in IPv6 format will be rejected if the system's C library does not have support for IPv6 addresses.

You can also write `all` to match any IP address, `samehost` to match any of the server's own IP addresses, or `samenet` to match any address in any subnet that the server is directly connected to.

If a host name is specified (anything that is not an IP address or a special key word is treated as a host name), that name is compared with the result of a reverse name resolution of the client's IP address (e.g., reverse DNS lookup, if DNS is used). Host name comparisons are case insensitive. If there is a match, then a forward name resolution (e.g., forward DNS lookup) is performed on the host name to check whether any of the addresses it resolves to are equal to the client's IP address. If both directions match, then the entry is considered to match. (The host name that is used in `pg_hba.conf` should be the one that address-to-name resolution of the client's IP address returns, otherwise the line won't be matched. Some host name databases allow associating an IP address with multiple host names, but the operating system will only return one host name when asked to resolve an IP address.)

A host name specification that starts with a dot (`.`) matches a suffix of the actual host name. So `.example.com` would match `foo.example.com` (but not just `example.com`).

When host names are specified in `pg_hba.conf`, you should make sure that name resolution is reasonably fast. It can be of advantage to set up a local name resolution cache such as `nscd`. Also, you may wish to enable the configuration parameter `log_hostname` to see the client's host name instead of the IP address in the log.

This field only applies to `host`, `hostssl`, and `hostnossl` records.

> Users sometimes wonder why host names are handled in this seemingly complicated way, with two name resolutions including a reverse lookup of the client's IP address. This complicates use of the feature in case the client's reverse DNS entry is not set up or yields some undesirable host name. It is done primarily for efficiency: this way, a connection attempt requires at most two resolver lookups, one reverse and one forward. If there is a resolver problem with some address, it becomes only that client's problem. A hypothetical alternative implementation that only did forward lookups would have to resolve every host name mentioned in `pg_hba.conf` during every connection attempt. That could be quite slow if many names are listed. And if there is a resolver problem with one of the host names, it becomes everyone's problem.
>
> Also, a reverse lookup is necessary to implement the suffix matching feature, because the actual client host name needs to be known in order to match it against the pattern.
>
> Note that this behavior is consistent with other popular implementations of host name-based access control, such as the Apache HTTP Server and TCP Wrappers.

IP-address
IP-mask

These fields can be used as an alternative to the *CIDR-address* notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, `255.0.0.0` represents an IPv4 CIDR mask length of 8, and `255.255.255.255` represents a CIDR mask length of 32.

These fields only apply to `host`, `hostssl`, and `hostnossl` records.

auth-method

Specifies the authentication method to use when a connection matches this record. The possible choices are summarized here; details are in Section 19.3.

`trust`

Allow the connection unconditionally. This method allows anyone that can connect to the PostgreSQL database server to login as any PostgreSQL user they wish, without the need for a password or any other authentication. See Section 19.3.1 for details.

`reject`

Reject the connection unconditionally. This is useful for "filtering out" certain hosts from a group, for example a `reject` line could block a specific host from connecting, while a later line allows the remaining hosts in a specific network to connect.

`md5`

Require the client to supply a double-MD5-hashed password for authentication. See Section 19.3.2 for details.

`password`

Require the client to supply an unencrypted password for authentication. Since the password is sent in clear text over the network, this should not be used on untrusted networks. See Section 19.3.2 for details.

`gss`

Use GSSAPI to authenticate the user. This is only available for TCP/IP connections. See Section 19.3.3 for details.

`sspi`

Use SSPI to authenticate the user. This is only available on Windows. See Section 19.3.4 for details.

`ident`

Obtain the operating system user name of the client by contacting the ident server on the client and check if it matches the requested database user name. Ident authentication can only be used on TCP/IP connections. When specified for local connections, peer authentication will be used instead. See Section 19.3.5 for details.

`peer`

Obtain the client's operating system user name from the operating system and check if it matches the requested database user name. This is only available for local connections. See Section 19.3.6 for details.

`ldap`

Authenticate using an LDAP server. See Section 19.3.7 for details.

`radius`

Authenticate using a RADIUS server. See Section 19.3.8 for details.

`cert`

Authenticate using SSL client certificates. See Section 19.3.9 for details.

`pam`

Authenticate using the Pluggable Authentication Modules (PAM) service provided by the operating system. See Section 19.3.10 for details.

auth-options

After the *auth-method* field, there can be field(s) of the form *name=value* that specify options for the authentication method. Details about which options are available for which authentication methods appear below.

Files included by `@` constructs are read as lists of names, which can be separated by either whitespace or commas. Comments are introduced by `#`, just as in `pg_hba.conf`, and nested `@` constructs are allowed. Unless the file name following `@` is an absolute path, it is taken to be relative to the directory containing the referencing file.

Since the `pg_hba.conf` records are examined sequentially for each connection attempt, the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example, one might wish to use `trust` authentication for local TCP/IP connections but require a password for remote TCP/IP connections. In this case a record specifying `trust` authentication for connections from 127.0.0.1 would appear before a record specifying password authentication for a wider range of allowed client IP addresses.

The `pg_hba.conf` file is read on start-up and when the main server process receives a SIGHUP signal. If you edit the file on an active system, you will need to signal the postmaster (using `pg_ctl reload` or `kill -HUP`) to make it re-read the file.

> **Tip:** To connect to a particular database, a user must not only pass the `pg_hba.conf` checks, but must have the `CONNECT` privilege for the database. If you wish to restrict which users can connect to which databases, it's usually easier to control this by granting/revoking `CONNECT` privilege than to put the rules in `pg_hba.conf` entries.

Some examples of `pg_hba.conf` entries are shown in Example 19-1. See the next section for details on the different authentication methods.

Example 19-1. Example `pg_hba.conf` Entries

```
# Allow any user on the local system to connect to any database with
# any database user name using Unix-domain sockets (the default for local
# connections).
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
local   all             all                                     trust

# The same using local loopback TCP/IP connections.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             127.0.0.1/32            trust

# The same as the previous line, but using a separate netmask column
#
# TYPE  DATABASE        USER            IP-ADDRESS      IP-MASK             METHOD
host    all             all             127.0.0.1       255.255.255.255     trust

# The same over IPv6.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             ::1/128                 trust

# The same using a host name (would typically cover both IPv4 and IPv6).
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             localhost               trust

# Allow any user from any host with IP address 192.168.93.x to connect
# to database "postgres" as the same user name that ident reports for
# the connection (typically the operating system user name).
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    postgres        all             192.168.93.0/24         ident

# Allow any user from host 192.168.12.10 to connect to database
# "postgres" if the user's password is correctly supplied.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    postgres        all             192.168.12.10/32        md5

# Allow any user from hosts in the example.com domain to connect to
```

```
# any database if the user's password is correctly supplied.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             .example.com            md5

# In the absence of preceding "host" lines, these two lines will
# reject all connections from 192.168.54.1 (since that entry will be
# matched first), but allow GSSAPI connections from anywhere else
# on the Internet.  The zero mask causes no bits of the host IP
# address to be considered, so it matches any host.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             192.168.54.1/32         reject
host    all             all             0.0.0.0/0               gss

# Allow users from 192.168.x.x hosts to connect to any database, if
# they pass the ident check.  If, for example, ident says the user is
# "bryanh" and he requests to connect as PostgreSQL user "guest1", the
# connection is allowed if there is an entry in pg_ident.conf for map
# "omicron" that says "bryanh" is allowed to connect as "guest1".
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    all             all             192.168.0.0/16          ident map=omicron

# If these are the only three lines for local connections, they will
# allow local users to connect only to their own databases (databases
# with the same name as their database user name) except for administrators
# and members of role "support", who can connect to all databases.  The file
# $PGDATA/admins contains a list of names of administrators.  Passwords
# are required in all cases.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
local   sameuser        all                                     md5
local   all             @admins                                 md5
local   all             +support                                md5

# The last two lines above can be combined into a single line:
local   all             @admins,+support                        md5

# The database column can also use lists and file names:
local   db1,db2,@demodbs  all                                   md5
```

19.2. User Name Maps

When using an external authentication system like Ident or GSSAPI, the name of the operating system user that initiated the connection might not be the same as the database user he needs to connect as. In this case, a user name map can be applied to map the operating system user name to a database user. To use user name mapping, specify `map=`*`map-name`* in the options field in `pg_hba.conf`. This option is supported for all authentication methods that receive external user names. Since different mappings might be needed for different connections, the name of the map to be used is specified in the *`map-name`* parameter in `pg_hba.conf` to indicate which map to use for each individual connection.

User name maps are defined in the ident map file, which by default is named `pg_ident.conf` and is stored in the cluster's data directory. (It is possible to place the map file elsewhere, however; see the ident_file configuration parameter.) The ident map file contains lines of the general form:

```
map-name system-username database-username
```

Comments and whitespace are handled in the same way as in `pg_hba.conf`. The *`map-name`* is an arbitrary name that will be used to refer to this mapping in `pg_hba.conf`. The other two fields specify an operating system user name and a matching database user name. The same *`map-name`* can be used repeatedly to specify multiple user-mappings within a single map.

There is no restriction regarding how many database users a given operating system user can correspond to, nor vice versa. Thus, entries in a map should be thought of as meaning "this operating system user is allowed to connect as this database user", rather than implying that they are equivalent. The connection will be allowed if there is any map entry that pairs the user name obtained from the external authentication system with the database user name that the user has requested to connect as.

If the *`system-username`* field starts with a slash (`/`), the remainder of the field is treated as a regular expression. (See Section 9.7.3.1 for details of PostgreSQL's regular expression syntax.) The regular expression can include a single capture, or parenthesized subexpression, which can then be referenced in the *`database-username`* field as `\1` (backslash-one). This allows the mapping of multiple user names in a single line, which is particularly useful for simple syntax substitutions. For example, these entries

```
mymap    /^(.*)@mydomain\.com$       \1
mymap    /^(.*)@otherdomain\.com$    guest
```

will remove the domain part for users with system user names that end with `@mydomain.com`, and allow any user whose system name ends with `@otherdomain.com` to log in as `guest`.

> **Tip:** Keep in mind that by default, a regular expression can match just part of a string. It's usually wise to use `^` and `$`, as shown in the above example, to force the match to be to the entire system user name.

The `pg_ident.conf` file is read on start-up and when the main server process receives a SIGHUP signal. If you edit the file on an active system, you will need to signal the postmaster (using `pg_ctl reload` or `kill -HUP`) to make it re-read the file.

A `pg_ident.conf` file that could be used in conjunction with the `pg_hba.conf` file in Example 19-1 is shown in Example 19-2. In this example, anyone logged in to a machine on the 192.168 network that does not have the operating system user name `bryanh`, `ann`, or `robert` would not be granted access. Unix user `robert` would only be allowed access when he tries to connect as PostgreSQL user `bob`, not as `robert` or anyone else. `ann` would only be allowed to connect as `ann`. User `bryanh` would be allowed to connect as either `bryanh` or as `guest1`.

Example 19-2. An Example `pg_ident.conf` File

```
# MAPNAME       SYSTEM-USERNAME         PG-USERNAME

omicron         bryanh                  bryanh
omicron         ann                     ann
# bob has user name robert on these machines
omicron         robert                  bob
# bryanh can also connect as guest1
omicron         bryanh                  guest1
```

19.3. Authentication Methods

The following subsections describe the authentication methods in more detail.

19.3.1. Trust Authentication

When `trust` authentication is specified, PostgreSQL assumes that anyone who can connect to the server is authorized to access the database with whatever database user name they specify (even superuser names). Of course, restrictions made in the `database` and `user` columns still apply. This method should only be used when there is adequate operating-system-level protection on connections to the server.

`trust` authentication is appropriate and very convenient for local connections on a single-user workstation. It is usually *not* appropriate by itself on a multiuser machine. However, you might be able to use `trust` even on a multiuser machine, if you restrict access to the server's Unix-domain socket file using file-system permissions. To do this, set the `unix_socket_permissions` (and possibly `unix_socket_group`) configuration parameters as described in Section 18.3. Or you could set the `unix_socket_directories` configuration parameter to place the socket file in a suitably restricted directory.

Setting file-system permissions only helps for Unix-socket connections. Local TCP/IP connections are not restricted by file-system permissions. Therefore, if you want to use file-system permissions for local security, remove the `host ... 127.0.0.1 ...` line from `pg_hba.conf`, or change it to a non-`trust` authentication method.

`trust` authentication is only suitable for TCP/IP connections if you trust every user on every machine that is allowed to connect to the server by the `pg_hba.conf` lines that specify `trust`. It is seldom reasonable to use `trust` for any TCP/IP connections other than those from localhost (127.0.0.1).

19.3.2. Password Authentication

The password-based authentication methods are `md5` and `password`. These methods operate similarly except for the way that the password is sent across the connection, namely MD5-hashed and clear-text respectively.

If you are at all concerned about password "sniffing" attacks then `md5` is preferred. Plain `password` should always be avoided if possible. However, `md5` cannot be used with the db_user_namespace feature. If the connection is protected by SSL encryption then `password` can be used safely (though SSL certificate authentication might be a better choice if one is depending on using SSL).

PostgreSQL database passwords are separate from operating system user passwords. The password for each database user is stored in the `pg_authid` system catalog. Passwords can be managed with the SQL commands CREATE USER and ALTER ROLE, e.g., **`CREATE USER foo WITH PASSWORD 'secret'`**. If no password has been set up for a user, the stored password is null and password authentication will always fail for that user.

19.3.3. GSSAPI Authentication

GSSAPI is an industry-standard protocol for secure authentication defined in RFC 2743. PostgreSQL supports GSSAPI with Kerberos authentication according to RFC 1964. GSSAPI provides automatic authentication (single sign-on) for systems that support it. The authentication itself is secure, but the data sent over the database connection will be sent unencrypted unless SSL is used.

GSSAPI support has to be enabled when PostgreSQL is built; see Chapter 15 for more information.

When GSSAPI uses Kerberos, it uses a standard principal in the format *servicename*/*hostname*@*realm*. The PostgreSQL server will accept any principal that is included in the keytab used by the server, but care needs to be taken to specify the correct principal details when making the connection from the client using the `krbsrvname` connection parameter. (See also Section 31.1.2.) The installation default can be changed from the default `postgres` at build time using `./configure --with-krb-srvnam=`*whatever*. In most environments, this parameter never needs to be changed. Some Kerberos implementations might require a different service name, such as Microsoft Active Directory which requires the service name to be in upper case (`POSTGRES`).

hostname is the fully qualified host name of the server machine. The service principal's realm is the preferred realm of the server machine.

Client principals must have their PostgreSQL database user name as their first component, for example `pgusername@realm`. Alternatively, you can use a user name mapping to map from the first component of the principal name to the database user name. By default, the realm of the client is not checked by PostgreSQL. If you have cross-realm authentication enabled and need to verify the realm, use the `krb_realm` parameter, or enable `include_realm` and use user name mapping to check the realm.

Make sure that your server keytab file is readable (and preferably only readable) by the PostgreSQL server account. (See also Section 17.1.) The location of the key file is specified by the krb_server_keyfile configuration parameter. The default is `/usr/local/pgsql/etc/krb5.keytab` (or whatever directory was specified as `sysconfdir` at build time). For security reasons, it is recommended to use a separate keytab just for the PostgreSQL server rather than opening up permissions on the system keytab file.

The keytab file is generated by the Kerberos software; see the Kerberos documentation for details. The following example is for MIT-compatible Kerberos 5 implementations:

```
kadmin% ank -randkey postgres/server.my.domain.org
kadmin% ktadd -k krb5.keytab postgres/server.my.domain.org
```

When connecting to the database make sure you have a ticket for a principal matching the requested database user name. For example, for database user name `fred`, principal `fred@EXAMPLE.COM` would be able to connect. To also allow principal `fred/users.example.com@EXAMPLE.COM`, use a user name map, as described in Section 19.2.

The following configuration options are supported for GSSAPI:

`include_realm`

If set to 1, the realm name from the authenticated user principal is included in the system user name that's passed through user name mapping (Section 19.2). This is useful for handling users from multiple realms.

`map`

Allows for mapping between system and database user names. See Section 19.2 for details. For a Kerberos principal `username/hostbased@EXAMPLE.COM`, the user name used for mapping is `username/hostbased` if `include_realm` is disabled, and `username/hostbased@EXAMPLE.COM` if `include_realm` is enabled.

`krb_realm`

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user

name mapping is done.

19.3.4. SSPI Authentication

SSPI is a Windows technology for secure authentication with single sign-on. PostgreSQL will use SSPI in `negotiate` mode, which will use Kerberos when possible and automatically fall back to NTLM in other cases. SSPI authentication only works when both server and client are running Windows, or, on non-Windows platforms, when GSSAPI is available.

When using Kerberos authentication, SSPI works the same way GSSAPI does; see Section 19.3.3 for details.

The following configuration options are supported for SSPI:

`include_realm`

If set to 1, the realm name from the authenticated user principal is included in the system user name that's passed through user name mapping (Section 19.2). This is useful for handling users from multiple realms.

`map`

Allows for mapping between system and database user names. See Section 19.2 for details.

`krb_realm`

Sets the realm to match user principal names against. If this parameter is set, only users of that realm will be accepted. If it is not set, users of any realm can connect, subject to whatever user name mapping is done.

19.3.5. Ident Authentication

The ident authentication method works by obtaining the client's operating system user name from an ident server and using it as the allowed database user name (with an optional user name mapping). This is only supported on TCP/IP connections.

Note: When ident is specified for a local (non-TCP/IP) connection, peer authentication (see Section 19.3.6) will be used instead.

The following configuration options are supported for ident:

`map`

Allows for mapping between system and database user names. See Section 19.2 for details.

The "Identification Protocol" is described in RFC 1413. Virtually every Unix-like operating system ships with an ident server that listens on TCP port 113 by default. The basic functionality of an ident server is to answer questions like "What user initiated the connection that goes out of your port *X* and connects to my port *Y*?". Since PostgreSQL knows both *X* and *Y* when a physical connection is

established, it can interrogate the ident server on the host of the connecting client and can theoretically determine the operating system user for any given connection.

The drawback of this procedure is that it depends on the integrity of the client: if the client machine is untrusted or compromised, an attacker could run just about any program on port 113 and return any user name he chooses. This authentication method is therefore only appropriate for closed networks where each client machine is under tight control and where the database and system administrators operate in close contact. In other words, you must trust the machine running the ident server. Heed the warning:

> The Identification Protocol is not intended as an authorization or access control protocol.
>
> —RFC 1413

Some ident servers have a nonstandard option that causes the returned user name to be encrypted, using a key that only the originating machine's administrator knows. This option *must not* be used when using the ident server with PostgreSQL, since PostgreSQL does not have any way to decrypt the returned string to determine the actual user name.

19.3.6. Peer Authentication

The peer authentication method works by obtaining the client's operating system user name from the kernel and using it as the allowed database user name (with optional user name mapping). This method is only supported on local connections.

The following configuration options are supported for peer:

`map`

Allows for mapping between system and database user names. See Section 19.2 for details.

Peer authentication is only available on operating systems providing the `getpeereid()` function, the `SO_PEERCRED` socket parameter, or similar mechanisms. Currently that includes Linux, most flavors of BSD including OS X, and Solaris.

19.3.7. LDAP Authentication

This authentication method operates similarly to `password` except that it uses LDAP as the password verification method. LDAP is used only to validate the user name/password pairs. Therefore the user must already exist in the database before LDAP can be used for authentication.

LDAP authentication can operate in two modes. In the first mode, which we will call the simple bind mode, the server will bind to the distinguished name constructed as *`prefix username suffix`*. Typically, the *`prefix`* parameter is used to specify `cn=`, or *`DOMAIN`*`\` in an Active Directory environment. *`suffix`* is used to specify the remaining part of the DN in a non-Active Directory environment.

In the second mode, which we will call the search+bind mode, the server first binds to the LDAP directory with a fixed user name and password, specified with *`ldapbinddn`* and *`ldapbindpasswd`*, and performs a search for the user trying to log in to the database. If no user and password is configured, an anonymous bind will be attempted to the directory. The search will be performed over the subtree at *`ldapbasedn`*, and will try to do an exact match of the attribute specified in *`ldapsearchattribute`*. Once the user has been found in this search, the server disconnects and re-binds to the directory as this user, using the password specified by the client, to verify that the login is correct. This mode is the same as that used by LDAP authentication schemes in other software, such as Apache

mod_authnz_ldap and pam_ldap. This method allows for significantly more flexibility in where the user objects are located in the directory, but will cause two separate connections to the LDAP server to be made.

The following configuration options are used in both modes:

`ldapserver`

Names or IP addresses of LDAP servers to connect to. Multiple servers may be specified, separated by spaces.

`ldapport`

Port number on LDAP server to connect to. If no port is specified, the LDAP library's default port setting will be used.

`ldaptls`

Set to 1 to make the connection between PostgreSQL and the LDAP server use TLS encryption. Note that this only encrypts the traffic to the LDAP server — the connection to the client will still be unencrypted unless SSL is used.

The following options are used in simple bind mode only:

`ldapprefix`

String to prepend to the user name when forming the DN to bind as, when doing simple bind authentication.

`ldapsuffix`

String to append to the user name when forming the DN to bind as, when doing simple bind authentication.

The following options are used in search+bind mode only:

`ldapbasedn`

Root DN to begin the search for the user in, when doing search+bind authentication.

`ldapbinddn`

DN of user to bind to the directory with to perform the search when doing search+bind authentication.

`ldapbindpasswd`

Password for user to bind to the directory with to perform the search when doing search+bind authentication.

`ldapsearchattribute`

Attribute to match against the user name in the search when doing search+bind authentication. If no attribute is specified, the `uid` attribute will be used.

`ldapurl`

An RFC 4516 LDAP URL. This is an alternative way to write some of the other LDAP options in a more compact and standard form. The format is

`ldap://`*`host`*`[:`*`port`*`]/`*`basedn`*`[?[`*`attribute`*`][?[`*`scope`*`]]]`
`scope` must be one of `base`, `one`, `sub`, typically the latter. Only one attribute is used, and some other components of standard LDAP URLs such as filters and extensions are not supported.

For non-anonymous binds, `ldapbinddn` and `ldapbindpasswd` must be specified as separate options.

To use encrypted LDAP connections, the `ldaptls` option has to be used in addition to `ldapurl`. The `ldaps` URL scheme (direct SSL connection) is not supported.

LDAP URLs are currently only supported with OpenLDAP, not on Windows.

It is an error to mix configuration options for simple bind with options for search+bind.

Here is an example for a simple-bind LDAP configuration:

```
host ... ldap ldapserver=ldap.example.net ldapprefix="cn=" ldapsuffix=", dc=example, dc=
```

When a connection to the database server as database user `someuser` is requested, PostgreSQL will attempt to bind to the LDAP server using the DN `cn=someuser, dc=example, dc=net` and the password provided by the client. If that connection succeeds, the database access is granted.

Here is an example for a search+bind configuration:

```
host ... ldap ldapserver=ldap.example.net ldapbasedn="dc=example, dc=net" ldapsearchattr
```

When a connection to the database server as database user `someuser` is requested, PostgreSQL will attempt to bind anonymously (since `ldapbinddn` was not specified) to the LDAP server, perform a search for `(uid=someuser)` under the specified base DN. If an entry is found, it will then attempt to bind using that found information and the password supplied by the client. If that second connection succeeds, the database access is granted.

Here is the same search+bind configuration written as a URL:

```
host ... ldap lapurl="ldap://ldap.example.net/dc=example,dc=net?uid?sub"
```

Some other software that supports authentication against LDAP uses the same URL format, so it will be easier to share the configuration.

Tip: Since LDAP often uses commas and spaces to separate the different parts of a DN, it is often necessary to use double-quoted parameter values when configuring LDAP options, as shown in the examples.

19.3.8. RADIUS Authentication

This authentication method operates similarly to `password` except that it uses RADIUS as the password verification method. RADIUS is used only to validate the user name/password pairs. Therefore the user must already exist in the database before RADIUS can be used for authentication.

When using RADIUS authentication, an Access Request message will be sent to the configured RADIUS server. This request will be of type `Authenticate Only`, and include parameters for `user name`, `password` (encrypted) and `NAS Identifier`. The request will be encrypted using a secret shared with the server. The RADIUS server will respond to this server with either `Access Accept` or `Access Reject`. There is no support for RADIUS accounting.

The following configuration options are supported for RADIUS:

`radiusserver`

The name or IP address of the RADIUS server to connect to. This parameter is required.

`radiussecret`

The shared secret used when talking securely to the RADIUS server. This must have exactly the same value on the PostgreSQL and RADIUS servers. It is recommended that this be a string of at least 16 characters. This parameter is required.

> **Note:** The encryption vector used will only be cryptographically strong if PostgreSQL is built with support for OpenSSL. In other cases, the transmission to the RADIUS server should only be considered obfuscated, not secured, and external security measures should be applied if necessary.

`radiusport`

The port number on the RADIUS server to connect to. If no port is specified, the default port `1812` will be used.

`radiusidentifier`

The string used as `NAS Identifier` in the RADIUS requests. This parameter can be used as a second parameter identifying for example which database user the user is attempting to authenticate as, which can be used for policy matching on the RADIUS server. If no identifier is specified, the default `postgresql` will be used.

19.3.9. Certificate Authentication

This authentication method uses SSL client certificates to perform authentication. It is therefore only available for SSL connections. When using this authentication method, the server will require that the client provide a valid certificate. No password prompt will be sent to the client. The `cn` (Common Name) attribute of the certificate will be compared to the requested database user name, and if they match the login will be allowed. User name mapping can be used to allow `cn` to be different from the database user name.

The following configuration options are supported for SSL certificate authentication:

`map`

Allows for mapping between system and database user names. See Section 19.2 for details.

19.3.10. PAM Authentication

This authentication method operates similarly to `password` except that it uses PAM (Pluggable Authentication Modules) as the authentication mechanism. The default PAM service name is `postgresql`. PAM is used only to validate user name/password pairs. Therefore the user must already exist in the database before PAM can be used for authentication. For more information about PAM, please read the Linux-PAM Page[1].

The following configuration options are supported for PAM:

1. http://www.kernel.org/pub/linux/libs/pam/

`pamservice`

PAM service name.

Note: If PAM is set up to read `/etc/shadow`, authentication will fail because the PostgreSQL server is started by a non-root user. However, this is not an issue when PAM is configured to use LDAP or other authentication methods.

19.4. Authentication Problems

Authentication failures and related problems generally manifest themselves through error messages like the following:

```
FATAL:  no pg_hba.conf entry for host "123.123.123.123", user "andym", database "testdb"
```

This is what you are most likely to get if you succeed in contacting the server, but it does not want to talk to you. As the message suggests, the server refused the connection request because it found no matching entry in its `pg_hba.conf` configuration file.

```
FATAL:  password authentication failed for user "andym"
```

Messages like this indicate that you contacted the server, and it is willing to talk to you, but not until you pass the authorization method specified in the `pg_hba.conf` file. Check the password you are providing, or check your Kerberos or ident software if the complaint mentions one of those authentication types.

```
FATAL:  user "andym" does not exist
```

The indicated database user name was not found.

```
FATAL:  database "testdb" does not exist
```

The database you are trying to connect to does not exist. Note that if you do not specify a database name, it defaults to the database user name, which might or might not be the right thing.

Tip: The server log might contain more information about an authentication failure than is reported to the client. If you are confused about the reason for a failure, check the server log.

Chapter 20. Database Roles

PostgreSQL manages database access permissions using the concept of *roles*. A role can be thought of as either a database user, or a group of database users, depending on how the role is set up. Roles can own database objects (for example, tables) and can assign privileges on those objects to other roles to control who has access to which objects. Furthermore, it is possible to grant *membership* in a role to another role, thus allowing the member role to use privileges assigned to another role.

The concept of roles subsumes the concepts of "users" and "groups". In PostgreSQL versions before 8.1, users and groups were distinct kinds of entities, but now there are only roles. Any role can act as a user, a group, or both.

This chapter describes how to create and manage roles. More information about the effects of role privileges on various database objects can be found in Section 5.6.

20.1. Database Roles

Database roles are conceptually completely separate from operating system users. In practice it might be convenient to maintain a correspondence, but this is not required. Database roles are global across a database cluster installation (and not per individual database). To create a role use the CREATE ROLE SQL command:

```
CREATE ROLE name;
```

name follows the rules for SQL identifiers: either unadorned without special characters, or double-quoted. (In practice, you will usually want to add additional options, such as LOGIN, to the command. More details appear below.) To remove an existing role, use the analogous DROP ROLE command:

```
DROP ROLE name;
```

For convenience, the programs createuser and dropuser are provided as wrappers around these SQL commands that can be called from the shell command line:

```
createuser name
dropuser name
```

To determine the set of existing roles, examine the pg_roles system catalog, for example

```
SELECT rolname FROM pg_roles;
```

The psql program's \du meta-command is also useful for listing the existing roles.

In order to bootstrap the database system, a freshly initialized system always contains one predefined role. This role is always a "superuser", and by default (unless altered when running initdb) it will have the same name as the operating system user that initialized the database cluster. Customarily, this role will be named postgres. In order to create more roles you first have to connect as this initial role.

Every connection to the database server is made using the name of some particular role, and this role determines the initial access privileges for commands issued in that connection. The role name to use for a particular database connection is indicated by the client that is initiating the connection request in an application-specific fashion. For example, the psql program uses the -U command line option

to indicate the role to connect as. Many applications assume the name of the current operating system user by default (including `createuser` and `psql`). Therefore it is often convenient to maintain a naming correspondence between roles and operating system users.

The set of database roles a given client connection can connect as is determined by the client authentication setup, as explained in Chapter 19. (Thus, a client is not limited to connect as the role matching its operating system user, just as a person's login name need not match her real name.) Since the role identity determines the set of privileges available to a connected client, it is important to carefully configure privileges when setting up a multiuser environment.

20.2. Role Attributes

A database role can have a number of attributes that define its privileges and interact with the client authentication system.

login privilege

Only roles that have the `LOGIN` attribute can be used as the initial role name for a database connection. A role with the `LOGIN` attribute can be considered the same as a "database user". To create a role with login privilege, use either:

```
CREATE ROLE name LOGIN;
CREATE USER name;
```

(`CREATE USER` is equivalent to `CREATE ROLE` except that `CREATE USER` assumes `LOGIN` by default, while `CREATE ROLE` does not.)

superuser status

A database superuser bypasses all permission checks, except the right to log in. This is a dangerous privilege and should not be used carelessly; it is best to do most of your work as a role that is not a superuser. To create a new database superuser, use `CREATE ROLE name SUPERUSER`. You must do this as a role that is already a superuser.

database creation

A role must be explicitly given permission to create databases (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEDB`.

role creation

A role must be explicitly given permission to create more roles (except for superusers, since those bypass all permission checks). To create such a role, use `CREATE ROLE name CREATEROLE`. A role with `CREATEROLE` privilege can alter and drop other roles, too, as well as grant or revoke membership in them. However, to create, alter, drop, or change membership of a superuser role, superuser status is required; `CREATEROLE` is insufficient for that.

initiating replication

A role must explicitly be given permission to initiate streaming replication (except for superusers, since those bypass all permission checks). A role used for streaming replication must always have `LOGIN` permission as well. To create such a role, use `CREATE ROLE name REPLICATION LOGIN`.

password

A password is only significant if the client authentication method requires the user to supply a password when connecting to the database. The `password` and `md5` authentication methods

make use of passwords. Database passwords are separate from operating system passwords. Specify a password upon role creation with `CREATE ROLE name PASSWORD 'string'`.

A role's attributes can be modified after creation with `ALTER ROLE`. See the reference pages for the CREATE ROLE and ALTER ROLE commands for details.

> **Tip:** It is good practice to create a role that has the `CREATEDB` and `CREATEROLE` privileges, but is not a superuser, and then use this role for all routine management of databases and roles. This approach avoids the dangers of operating as a superuser for tasks that do not really require it.

A role can also have role-specific defaults for many of the run-time configuration settings described in Chapter 18. For example, if for some reason you want to disable index scans (hint: not a good idea) anytime you connect, you can use:

```
ALTER ROLE myname SET enable_indexscan TO off;
```

This will save the setting (but not set it immediately). In subsequent connections by this role it will appear as though `SET enable_indexscan TO off` had been executed just before the session started. You can still alter this setting during the session; it will only be the default. To remove a role-specific default setting, use `ALTER ROLE rolename RESET varname`. Note that role-specific defaults attached to roles without `LOGIN` privilege are fairly useless, since they will never be invoked.

20.3. Role Membership

It is frequently convenient to group users together to ease management of privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In PostgreSQL this is done by creating a role that represents the group, and then granting *membership* in the group role to individual user roles.

To set up a group role, first create the role:

```
CREATE ROLE name;
```

Typically a role being used as a group would not have the `LOGIN` attribute, though you can set it if you wish.

Once the group role exists, you can add and remove members using the GRANT and REVOKE commands:

```
GRANT group_role TO role1, ... ;
REVOKE group_role FROM role1, ... ;
```

You can grant membership to other group roles, too (since there isn't really any distinction between group roles and non-group roles). The database will not let you set up circular membership loops. Also, it is not permitted to grant membership in a role to `PUBLIC`.

The members of a group role can use the privileges of the role in two ways. First, every member of a group can explicitly do SET ROLE to temporarily "become" the group role. In this state, the database session has access to the privileges of the group role rather than the original login role, and any database objects created are considered owned by the group role not the login role. Second, member roles that have the `INHERIT` attribute automatically have use of the privileges of roles of which they are members, including any privileges inherited by those roles. As an example, suppose we have done:

```
CREATE ROLE joe LOGIN INHERIT;
CREATE ROLE admin NOINHERIT;
CREATE ROLE wheel NOINHERIT;
GRANT admin TO joe;
GRANT wheel TO admin;
```

Immediately after connecting as role `joe`, a database session will have use of privileges granted directly to `joe` plus any privileges granted to `admin`, because `joe` "inherits" `admin`'s privileges. However, privileges granted to `wheel` are not available, because even though `joe` is indirectly a member of `wheel`, the membership is via `admin` which has the `NOINHERIT` attribute. After:

```
SET ROLE admin;
```

the session would have use of only those privileges granted to `admin`, and not those granted to `joe`. After:

```
SET ROLE wheel;
```

the session would have use of only those privileges granted to `wheel`, and not those granted to either `joe` or `admin`. The original privilege state can be restored with any of:

```
SET ROLE joe;
SET ROLE NONE;
RESET ROLE;
```

Note: The `SET ROLE` command always allows selecting any role that the original login role is directly or indirectly a member of. Thus, in the above example, it is not necessary to become `admin` before becoming `wheel`.

Note: In the SQL standard, there is a clear distinction between users and roles, and users do not automatically inherit privileges while roles do. This behavior can be obtained in PostgreSQL by giving roles being used as SQL roles the `INHERIT` attribute, while giving roles being used as SQL users the `NOINHERIT` attribute. However, PostgreSQL defaults to giving all roles the `INHERIT` attribute, for backward compatibility with pre-8.1 releases in which users always had use of permissions granted to groups they were members of.

The role attributes `LOGIN`, `SUPERUSER`, `CREATEDB`, and `CREATEROLE` can be thought of as special privileges, but they are never inherited as ordinary privileges on database objects are. You must actually `SET ROLE` to a specific role having one of these attributes in order to make use of the attribute. Continuing the above example, we might choose to grant `CREATEDB` and `CREATEROLE` to the `admin` role. Then a session connecting as role `joe` would not have these privileges immediately, only after doing `SET ROLE admin`.

To destroy a group role, use DROP ROLE:

```
DROP ROLE name;
```

Any memberships in the group role are automatically revoked (but the member roles are not otherwise affected). Note however that any objects owned by the group role must first be dropped or reassigned to other owners; and any permissions granted to the group role must be revoked.

20.4. Function and Trigger Security

Functions and triggers allow users to insert code into the backend server that other users might execute unintentionally. Hence, both mechanisms permit users to "Trojan horse" others with relative ease. The only real protection is tight control over who can define functions.

Functions run inside the backend server process with the operating system permissions of the database server daemon. If the programming language used for the function allows unchecked memory accesses, it is possible to change the server's internal data structures. Hence, among many other things, such functions can circumvent any system access controls. Function languages that allow such access are considered "untrusted", and PostgreSQL allows only superusers to create functions written in those languages.

Chapter 21. Managing Databases

Every instance of a running PostgreSQL server manages one or more databases. Databases are therefore the topmost hierarchical level for organizing SQL objects ("database objects"). This chapter describes the properties of databases, and how to create, manage, and destroy them.

21.1. Overview

A database is a named collection of SQL objects ("database objects"). Generally, every database object (tables, functions, etc.) belongs to one and only one database. (However there are a few system catalogs, for example `pg_database`, that belong to a whole cluster and are accessible from each database within the cluster.) More accurately, a database is a collection of schemas and the schemas contain the tables, functions, etc. So the full hierarchy is: server, database, schema, table (or some other kind of object, such as a function).

When connecting to the database server, a client must specify in its connection request the name of the database it wants to connect to. It is not possible to access more than one database per connection. However, an application is not restricted in the number of connections it opens to the same or other databases. Databases are physically separated and access control is managed at the connection level. If one PostgreSQL server instance is to house projects or users that should be separate and for the most part unaware of each other, it is therefore recommended to put them into separate databases. If the projects or users are interrelated and should be able to use each other's resources, they should be put in the same database but possibly into separate schemas. Schemas are a purely logical structure and who can access what is managed by the privilege system. More information about managing schemas is in Section 5.7.

Databases are created with the `CREATE DATABASE` command (see Section 21.2) and destroyed with the `DROP DATABASE` command (see Section 21.5). To determine the set of existing databases, examine the `pg_database` system catalog, for example

```
SELECT datname FROM pg_database;
```

The psql program's `\l` meta-command and `-l` command-line option are also useful for listing the existing databases.

Note: The SQL standard calls databases "catalogs", but there is no difference in practice.

21.2. Creating a Database

In order to create a database, the PostgreSQL server must be up and running (see Section 17.3).

Databases are created with the SQL command CREATE DATABASE:

```
CREATE DATABASE name;
```

where *name* follows the usual rules for SQL identifiers. The current role automatically becomes the owner of the new database. It is the privilege of the owner of a database to remove it later (which also removes all the objects in it, even if they have a different owner).

The creation of databases is a restricted operation. See Section 20.2 for how to grant permission.

Since you need to be connected to the database server in order to execute the CREATE DATABASE command, the question remains how the *first* database at any given site can be created. The first database is always created by the initdb command when the data storage area is initialized. (See Section 17.2.) This database is called postgres. So to create the first "ordinary" database you can connect to postgres.

A second database, template1, is also created during database cluster initialization. Whenever a new database is created within the cluster, template1 is essentially cloned. This means that any changes you make in template1 are propagated to all subsequently created databases. Because of this, avoid creating objects in template1 unless you want them propagated to every newly created database. More details appear in Section 21.3.

As a convenience, there is a program you can execute from the shell to create new databases, createdb.

```
createdb dbname
```

createdb does no magic. It connects to the postgres database and issues the CREATE DATABASE command, exactly as described above. The createdb reference page contains the invocation details. Note that createdb without any arguments will create a database with the current user name.

Note: Chapter 19 contains information about how to restrict who can connect to a given database.

Sometimes you want to create a database for someone else, and have him become the owner of the new database, so he can configure and manage it himself. To achieve that, use one of the following commands:

```
CREATE DATABASE dbname OWNER rolename;
```

from the SQL environment, or:

```
createdb -O rolename dbname
```

from the shell. Only the superuser is allowed to create a database for someone else (that is, for a role you are not a member of).

21.3. Template Databases

CREATE DATABASE actually works by copying an existing database. By default, it copies the standard system database named template1. Thus that database is the "template" from which new databases are made. If you add objects to template1, these objects will be copied into subsequently created user databases. This behavior allows site-local modifications to the standard set of objects in databases. For example, if you install the procedural language PL/Perl in template1, it will automatically be available in user databases without any extra action being taken when those databases are created.

There is a second standard system database named template0. This database contains the same data as the initial contents of template1, that is, only the standard objects predefined by your version of PostgreSQL. template0 should never be changed after the database cluster has been initialized. By instructing CREATE DATABASE to copy template0 instead of template1, you can create a "virgin" user database that contains none of the site-local additions in template1. This is particularly handy when restoring a pg_dump dump: the dump script should be restored in a virgin database to ensure

that one recreates the correct contents of the dumped database, without conflicting with objects that might have been added to `template1` later on.

Another common reason for copying `template0` instead of `template1` is that new encoding and locale settings can be specified when copying `template0`, whereas a copy of `template1` must use the same settings it does. This is because `template1` might contain encoding-specific or locale-specific data, while `template0` is known not to.

To create a database by copying `template0`, use:

```
CREATE DATABASE dbname TEMPLATE template0;
```

from the SQL environment, or:

```
createdb -T template0 dbname
```

from the shell.

It is possible to create additional template databases, and indeed one can copy any database in a cluster by specifying its name as the template for `CREATE DATABASE`. It is important to understand, however, that this is not (yet) intended as a general-purpose "`COPY DATABASE`" facility. The principal limitation is that no other sessions can be connected to the source database while it is being copied. `CREATE DATABASE` will fail if any other connection exists when it starts; during the copy operation, new connections to the source database are prevented.

Two useful flags exist in `pg_database` for each database: the columns `datistemplate` and `datallowconn`. `datistemplate` can be set to indicate that a database is intended as a template for `CREATE DATABASE`. If this flag is set, the database can be cloned by any user with `CREATEDB` privileges; if it is not set, only superusers and the owner of the database can clone it. If `datallowconn` is false, then no new connections to that database will be allowed (but existing sessions are not terminated simply by setting the flag false). The `template0` database is normally marked `datallowconn = false` to prevent its modification. Both `template0` and `template1` should always be marked with `datistemplate = true`.

> **Note:** `template1` and `template0` do not have any special status beyond the fact that the name `template1` is the default source database name for `CREATE DATABASE`. For example, one could drop `template1` and recreate it from `template0` without any ill effects. This course of action might be advisable if one has carelessly added a bunch of junk in `template1`. (To delete `template1`, it must have `pg_database.datistemplate = false`.)
>
> The `postgres` database is also created when a database cluster is initialized. This database is meant as a default database for users and applications to connect to. It is simply a copy of `template1` and can be dropped and recreated if necessary.

21.4. Database Configuration

Recall from Chapter 18 that the PostgreSQL server provides a large number of run-time configuration variables. You can set database-specific default values for many of these settings.

For example, if for some reason you want to disable the GEQO optimizer for a given database, you'd ordinarily have to either disable it for all databases or make sure that every connecting client is careful to issue `SET geqo TO off`. To make this setting the default within a particular database, you can execute the command:

```
ALTER DATABASE mydb SET geqo TO off;
```

This will save the setting (but not set it immediately). In subsequent connections to this database it will appear as though `SET geqo TO off;` had been executed just before the session started. Note that users can still alter this setting during their sessions; it will only be the default. To undo any such setting, use `ALTER DATABASE dbname RESET varname`.

21.5. Destroying a Database

Databases are destroyed with the command DROP DATABASE:

```
DROP DATABASE name;
```

Only the owner of the database, or a superuser, can drop a database. Dropping a database removes all objects that were contained within the database. The destruction of a database cannot be undone.

You cannot execute the `DROP DATABASE` command while connected to the victim database. You can, however, be connected to any other database, including the `template1` database. `template1` would be the only option for dropping the last user database of a given cluster.

For convenience, there is also a shell program to drop databases, dropdb:

```
dropdb dbname
```

(Unlike `createdb`, it is not the default action to drop the database with the current user name.)

21.6. Tablespaces

Tablespaces in PostgreSQL allow database administrators to define locations in the file system where the files representing database objects can be stored. Once created, a tablespace can be referred to by name when creating database objects.

By using tablespaces, an administrator can control the disk layout of a PostgreSQL installation. This is useful in at least two ways. First, if the partition or volume on which the cluster was initialized runs out of space and cannot be extended, a tablespace can be created on a different partition and used until the system can be reconfigured.

Second, tablespaces allow an administrator to use knowledge of the usage pattern of database objects to optimize performance. For example, an index which is very heavily used can be placed on a very fast, highly available disk, such as an expensive solid state device. At the same time a table storing archived data which is rarely used or not performance critical could be stored on a less expensive, slower disk system.

Warning

Even though located outside the main PostgreSQL data directory, tablespaces are an integral part of the database cluster and *cannot* be treated as an autonomous collection of data files. They are dependent on metadata contained in the main data directory, and therefore cannot be attached to a different database cluster or backed up individually. Similarly, if you lose a tablespace (file deletion, disk failure, etc), the database cluster might become unreadable or unable to start. Placing a tablespace on a temporary file system like a ramdisk risks the reliability of the entire cluster.

To define a tablespace, use the CREATE TABLESPACE command, for example::

```
CREATE TABLESPACE fastspace LOCATION '/ssd1/postgresql/data';
```

The location must be an existing, empty directory that is owned by the PostgreSQL operating system user. All objects subsequently created within the tablespace will be stored in files underneath this directory. The location must not be on removable or transient storage, as the cluster might fail to function if the tablespace is missing or lost.

> **Note:** There is usually not much point in making more than one tablespace per logical file system, since you cannot control the location of individual files within a logical file system. However, PostgreSQL does not enforce any such limitation, and indeed it is not directly aware of the file system boundaries on your system. It just stores files in the directories you tell it to use.

Creation of the tablespace itself must be done as a database superuser, but after that you can allow ordinary database users to use it. To do that, grant them the `CREATE` privilege on it.

Tables, indexes, and entire databases can be assigned to particular tablespaces. To do so, a user with the `CREATE` privilege on a given tablespace must pass the tablespace name as a parameter to the relevant command. For example, the following creates a table in the tablespace `space1`:

```
CREATE TABLE foo(i int) TABLESPACE space1;
```

Alternatively, use the default_tablespace parameter:

```
SET default_tablespace = space1;
CREATE TABLE foo(i int);
```

When `default_tablespace` is set to anything but an empty string, it supplies an implicit `TABLESPACE` clause for `CREATE TABLE` and `CREATE INDEX` commands that do not have an explicit one.

There is also a temp_tablespaces parameter, which determines the placement of temporary tables and indexes, as well as temporary files that are used for purposes such as sorting large data sets. This can be a list of tablespace names, rather than only one, so that the load associated with temporary objects can be spread over multiple tablespaces. A random member of the list is picked each time a temporary object is to be created.

The tablespace associated with a database is used to store the system catalogs of that database. Furthermore, it is the default tablespace used for tables, indexes, and temporary files created within the database, if no `TABLESPACE` clause is given and no other selection is specified by `default_tablespace` or `temp_tablespaces` (as appropriate). If a database is created without specifying a tablespace for it, it uses the same tablespace as the template database it is copied from.

Two tablespaces are automatically created when the database cluster is initialized. The `pg_global` tablespace is used for shared system catalogs. The `pg_default` tablespace is the default tablespace of the `template1` and `template0` databases (and, therefore, will be the default tablespace for other databases as well, unless overridden by a `TABLESPACE` clause in `CREATE DATABASE`).

Once created, a tablespace can be used from any database, provided the requesting user has sufficient privilege. This means that a tablespace cannot be dropped until all objects in all databases using the tablespace have been removed.

To remove an empty tablespace, use the DROP TABLESPACE command.

To determine the set of existing tablespaces, examine the `pg_tablespace` system catalog, for example

```
SELECT spcname FROM pg_tablespace;
```

The psql program's `\db` meta-command is also useful for listing the existing tablespaces.

PostgreSQL makes use of symbolic links to simplify the implementation of tablespaces. This means that tablespaces can be used *only* on systems that support symbolic links.

The directory `$PGDATA/pg_tblspc` contains symbolic links that point to each of the non-built-in tablespaces defined in the cluster. Although not recommended, it is possible to adjust the tablespace layout by hand by redefining these links. Under no circumstances perform this operation while the server is running. Note that in PostgreSQL 9.1 and earlier you will also need to update the `pg_tablespace` catalog with the new locations. (If you do not, `pg_dump` will continue to output the old tablespace locations.)

Chapter 22. Localization

This chapter describes the available localization features from the point of view of the administrator. PostgreSQL supports two localization facilities:

- Using the locale features of the operating system to provide locale-specific collation order, number formatting, translated messages, and other aspects. This is covered in Section 22.1 and Section 22.2.
- Providing a number of different character sets to support storing text in all kinds of languages, and providing character set translation between client and server. This is covered in Section 22.3.

22.1. Locale Support

Locale support refers to an application respecting cultural preferences regarding alphabets, sorting, number formatting, etc. PostgreSQL uses the standard ISO C and POSIX locale facilities provided by the server operating system. For additional information refer to the documentation of your system.

22.1.1. Overview

Locale support is automatically initialized when a database cluster is created using `initdb`. `initdb` will initialize the database cluster with the locale setting of its execution environment by default, so if your system is already set to use the locale that you want in your database cluster then there is nothing else you need to do. If you want to use a different locale (or you are not sure which locale your system is set to), you can instruct `initdb` exactly which locale to use by specifying the `--locale` option. For example:

```
initdb --locale=sv_SE
```

This example for Unix systems sets the locale to Swedish (`sv`) as spoken in Sweden (`SE`). Other possibilities might include `en_US` (U.S. English) and `fr_CA` (French Canadian). If more than one character set can be used for a locale then the specifications can take the form *`language_territory.codeset`*. For example, `fr_BE.UTF-8` represents the French language (fr) as spoken in Belgium (BE), with a UTF-8 character set encoding.

What locales are available on your system under what names depends on what was provided by the operating system vendor and what was installed. On most Unix systems, the command `locale -a` will provide a list of available locales. Windows uses more verbose locale names, such as `German_Germany` or `Swedish_Sweden.1252`, but the principles are the same.

Occasionally it is useful to mix rules from several locales, e.g., use English collation rules but Spanish messages. To support that, a set of locale subcategories exist that control only certain aspects of the localization rules:

`LC_COLLATE`	String sort order
`LC_CTYPE`	Character classification (What is a letter? Its upper-case equivalent?)

LC_MESSAGES	Language of messages
LC_MONETARY	Formatting of currency amounts
LC_NUMERIC	Formatting of numbers
LC_TIME	Formatting of dates and times

The category names translate into names of initdb options to override the locale choice for a specific category. For instance, to set the locale to French Canadian, but use U.S. rules for formatting currency, use initdb --locale=fr_CA --lc-monetary=en_US.

If you want the system to behave as if it had no locale support, use the special locale name C, or equivalently POSIX.

Some locale categories must have their values fixed when the database is created. You can use different settings for different databases, but once a database is created, you cannot change them for that database anymore. LC_COLLATE and LC_CTYPE are these categories. They affect the sort order of indexes, so they must be kept fixed, or indexes on text columns would become corrupt. (But you can alleviate this restriction using collations, as discussed in Section 22.2.) The default values for these categories are determined when initdb is run, and those values are used when new databases are created, unless specified otherwise in the CREATE DATABASE command.

The other locale categories can be changed whenever desired by setting the server configuration parameters that have the same name as the locale categories (see Section 18.11.2 for details). The values that are chosen by initdb are actually only written into the configuration file postgresql.conf to serve as defaults when the server is started. If you remove these assignments from postgresql.conf then the server will inherit the settings from its execution environment.

Note that the locale behavior of the server is determined by the environment variables seen by the server, not by the environment of any client. Therefore, be careful to configure the correct locale settings before starting the server. A consequence of this is that if client and server are set up in different locales, messages might appear in different languages depending on where they originated.

> **Note:** When we speak of inheriting the locale from the execution environment, this means the following on most operating systems: For a given locale category, say the collation, the following environment variables are consulted in this order until one is found to be set: LC_ALL, LC_COLLATE (or the variable corresponding to the respective category), LANG. If none of these environment variables are set then the locale defaults to C.
>
> Some message localization libraries also look at the environment variable LANGUAGE which overrides all other locale settings for the purpose of setting the language of messages. If in doubt, please refer to the documentation of your operating system, in particular the documentation about gettext.

To enable messages to be translated to the user's preferred language, NLS must have been selected at build time (configure --enable-nls). All other locale support is built in automatically.

22.1.2. Behavior

The locale settings influence the following SQL features:

- Sort order in queries using ORDER BY or the standard comparison operators on textual data
- The upper, lower, and initcap functions

- Pattern matching operators (LIKE, SIMILAR TO, and POSIX-style regular expressions); locales affect both case insensitive matching and the classification of characters by character-class regular expressions
- The to_char family of functions
- The ability to use indexes with LIKE clauses

The drawback of using locales other than C or POSIX in PostgreSQL is its performance impact. It slows character handling and prevents ordinary indexes from being used by LIKE. For this reason use locales only if you actually need them.

As a workaround to allow PostgreSQL to use indexes with LIKE clauses under a non-C locale, several custom operator classes exist. These allow the creation of an index that performs a strict character-by-character comparison, ignoring locale comparison rules. Refer to Section 11.9 for more information. Another approach is to create indexes using the C collation, as discussed in Section 22.2.

22.1.3. Problems

If locale support doesn't work according to the explanation above, check that the locale support in your operating system is correctly configured. To check what locales are installed on your system, you can use the command locale -a if your operating system provides it.

Check that PostgreSQL is actually using the locale that you think it is. The LC_COLLATE and LC_CTYPE settings are determined when a database is created, and cannot be changed except by creating a new database. Other locale settings including LC_MESSAGES and LC_MONETARY are initially determined by the environment the server is started in, but can be changed on-the-fly. You can check the active locale settings using the SHOW command.

The directory src/test/locale in the source distribution contains a test suite for PostgreSQL's locale support.

Client applications that handle server-side errors by parsing the text of the error message will obviously have problems when the server's messages are in a different language. Authors of such applications are advised to make use of the error code scheme instead.

Maintaining catalogs of message translations requires the on-going efforts of many volunteers that want to see PostgreSQL speak their preferred language well. If messages in your language are currently not available or not fully translated, your assistance would be appreciated. If you want to help, refer to Chapter 51 or write to the developers' mailing list.

22.2. Collation Support

The collation feature allows specifying the sort order and character classification behavior of data per-column, or even per-operation. This alleviates the restriction that the LC_COLLATE and LC_CTYPE settings of a database cannot be changed after its creation.

22.2.1. Concepts

Conceptually, every expression of a collatable data type has a collation. (The built-in collatable data types are text, varchar, and char. User-defined base types can also be marked collatable, and of

course a domain over a collatable data type is collatable.) If the expression is a column reference, the collation of the expression is the defined collation of the column. If the expression is a constant, the collation is the default collation of the data type of the constant. The collation of a more complex expression is derived from the collations of its inputs, as described below.

The collation of an expression can be the "default" collation, which means the locale settings defined for the database. It is also possible for an expression's collation to be indeterminate. In such cases, ordering operations and other operations that need to know the collation will fail.

When the database system has to perform an ordering or a character classification, it uses the collation of the input expression. This happens, for example, with `ORDER BY` clauses and function or operator calls such as <. The collation to apply for an `ORDER BY` clause is simply the collation of the sort key. The collation to apply for a function or operator call is derived from the arguments, as described below. In addition to comparison operators, collations are taken into account by functions that convert between lower and upper case letters, such as `lower`, `upper`, and `initcap`; by pattern matching operators; and by `to_char` and related functions.

For a function or operator call, the collation that is derived by examining the argument collations is used at run time for performing the specified operation. If the result of the function or operator call is of a collatable data type, the collation is also used at parse time as the defined collation of the function or operator expression, in case there is a surrounding expression that requires knowledge of its collation.

The *collation derivation* of an expression can be implicit or explicit. This distinction affects how collations are combined when multiple different collations appear in an expression. An explicit collation derivation occurs when a `COLLATE` clause is used; all other collation derivations are implicit. When multiple collations need to be combined, for example in a function call, the following rules are used:

1. If any input expression has an explicit collation derivation, then all explicitly derived collations among the input expressions must be the same, otherwise an error is raised. If any explicitly derived collation is present, that is the result of the collation combination.
2. Otherwise, all input expressions must have the same implicit collation derivation or the default collation. If any non-default collation is present, that is the result of the collation combination. Otherwise, the result is the default collation.
3. If there are conflicting non-default implicit collations among the input expressions, then the combination is deemed to have indeterminate collation. This is not an error condition unless the particular function being invoked requires knowledge of the collation it should apply. If it does, an error will be raised at run-time.

For example, consider this table definition:

```
CREATE TABLE test1 (
    a text COLLATE "de_DE",
    b text COLLATE "es_ES",
    ...
);
```

Then in

```
SELECT a < 'foo' FROM test1;
```

the < comparison is performed according to `de_DE` rules, because the expression combines an implicitly derived collation with the default collation. But in

```
SELECT a < ('foo' COLLATE "fr_FR") FROM test1;
```

the comparison is performed using fr_FR rules, because the explicit collation derivation overrides the implicit one. Furthermore, given

```
SELECT a < b FROM test1;
```

the parser cannot determine which collation to apply, since the a and b columns have conflicting implicit collations. Since the < operator does need to know which collation to use, this will result in an error. The error can be resolved by attaching an explicit collation specifier to either input expression, thus:

```
SELECT a < b COLLATE "de_DE" FROM test1;
```

or equivalently

```
SELECT a COLLATE "de_DE" < b FROM test1;
```

On the other hand, the structurally similar case

```
SELECT a || b FROM test1;
```

does not result in an error, because the || operator does not care about collations: its result is the same regardless of the collation.

The collation assigned to a function or operator's combined input expressions is also considered to apply to the function or operator's result, if the function or operator delivers a result of a collatable data type. So, in

```
SELECT * FROM test1 ORDER BY a || 'foo';
```

the ordering will be done according to de_DE rules. But this query:

```
SELECT * FROM test1 ORDER BY a || b;
```

results in an error, because even though the || operator doesn't need to know a collation, the ORDER BY clause does. As before, the conflict can be resolved with an explicit collation specifier:

```
SELECT * FROM test1 ORDER BY a || b COLLATE "fr_FR";
```

22.2.2. Managing Collations

A collation is an SQL schema object that maps an SQL name to operating system locales. In particular, it maps to a combination of LC_COLLATE and LC_CTYPE. (As the name would suggest, the main purpose of a collation is to set LC_COLLATE, which controls the sort order. But it is rarely necessary in practice to have an LC_CTYPE setting that is different from LC_COLLATE, so it is more convenient to collect these under one concept than to create another infrastructure for setting LC_CTYPE per expression.) Also, a collation is tied to a character set encoding (see Section 22.3). The same collation name may exist for different encodings.

On all platforms, the collations named default, C, and POSIX are available. Additional collations may be available depending on operating system support. The default collation selects the LC_COLLATE and LC_CTYPE values specified at database creation time. The C and POSIX collations both specify "traditional C" behavior, in which only the ASCII letters "A" through "Z" are treated as letters, and sorting is done strictly by character code byte values.

If the operating system provides support for using multiple locales within a single program (`newlocale` and related functions), then when a database cluster is initialized, `initdb` populates the system catalog `pg_collation` with collations based on all the locales it finds on the operating system at the time. For example, the operating system might provide a locale named `de_DE.utf8`. `initdb` would then create a collation named `de_DE.utf8` for encoding `UTF8` that has both `LC_COLLATE` and `LC_CTYPE` set to `de_DE.utf8`. It will also create a collation with the `.utf8` tag stripped off the name. So you could also use the collation under the name `de_DE`, which is less cumbersome to write and makes the name less encoding-dependent. Note that, nevertheless, the initial set of collation names is platform-dependent.

In case a collation is needed that has different values for `LC_COLLATE` and `LC_CTYPE`, a new collation may be created using the CREATE COLLATION command. That command can also be used to create a new collation from an existing collation, which can be useful to be able to use operating-system-independent collation names in applications.

Within any particular database, only collations that use that database's encoding are of interest. Other entries in `pg_collation` are ignored. Thus, a stripped collation name such as `de_DE` can be considered unique within a given database even though it would not be unique globally. Use of the stripped collation names is recommended, since it will make one less thing you need to change if you decide to change to another database encoding. Note however that the `default`, `C`, and `POSIX` collations can be used regardless of the database encoding.

PostgreSQL considers distinct collation objects to be incompatible even when they have identical properties. Thus for example,

```
SELECT a COLLATE "C" < b COLLATE "POSIX" FROM test1;
```

will draw an error even though the `C` and `POSIX` collations have identical behaviors. Mixing stripped and non-stripped collation names is therefore not recommended.

22.3. Character Set Support

The character set support in PostgreSQL allows you to store text in a variety of character sets (also called encodings), including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your PostgreSQL database cluster using `initdb`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

An important restriction, however, is that each database's character set must be compatible with the database's `LC_CTYPE` (character classification) and `LC_COLLATE` (string sort order) locale settings. For `C` or `POSIX` locale, any character set is allowed, but for other locales there is only one character set that will work correctly. (On Windows, however, UTF-8 encoding can be used with any locale.)

22.3.1. Supported Character Sets

Table 22-1 shows the character sets available for use in PostgreSQL.

Table 22-1. PostgreSQL Character Sets

Name	Description	Language	Server?	Bytes/Char	Aliases
BIG5	Big Five	Traditional Chinese	No	1-2	WIN950, Windows950
EUC_CN	Extended UNIX Code-CN	Simplified Chinese	Yes	1-3	
EUC_JP	Extended UNIX Code-JP	Japanese	Yes	1-3	
EUC_JIS_2004	Extended UNIX Code-JP, JIS X 0213	Japanese	Yes	1-3	
EUC_KR	Extended UNIX Code-KR	Korean	Yes	1-3	
EUC_TW	Extended UNIX Code-TW	Traditional Chinese, Taiwanese	Yes	1-3	
GB18030	National Standard	Chinese	No	1-2	
GBK	Extended National Standard	Simplified Chinese	No	1-2	WIN936, Windows936
ISO_8859_5	ISO 8859-5, ECMA 113	Latin/Cyrillic	Yes	1	
ISO_8859_6	ISO 8859-6, ECMA 114	Latin/Arabic	Yes	1	
ISO_8859_7	ISO 8859-7, ECMA 118	Latin/Greek	Yes	1	
ISO_8859_8	ISO 8859-8, ECMA 121	Latin/Hebrew	Yes	1	
JOHAB	JOHAB	Korean (Hangul)	No	1-3	
KOI8R	KOI8-R	Cyrillic (Russian)	Yes	1	KOI8
KOI8U	KOI8-U	Cyrillic (Ukrainian)	Yes	1	
LATIN1	ISO 8859-1, ECMA 94	Western European	Yes	1	ISO88591
LATIN2	ISO 8859-2, ECMA 94	Central European	Yes	1	ISO88592
LATIN3	ISO 8859-3, ECMA 94	South European	Yes	1	ISO88593
LATIN4	ISO 8859-4, ECMA 94	North European	Yes	1	ISO88594

Name	Description	Language	Server?	Bytes/Char	Aliases
LATIN5	ISO 8859-9, ECMA 128	Turkish	Yes	1	ISO88599
LATIN6	ISO 8859-10, ECMA 144	Nordic	Yes	1	ISO885910
LATIN7	ISO 8859-13	Baltic	Yes	1	ISO885913
LATIN8	ISO 8859-14	Celtic	Yes	1	ISO885914
LATIN9	ISO 8859-15	LATIN1 with Euro and accents	Yes	1	ISO885915
LATIN10	ISO 8859-16, ASRO SR 14111	Romanian	Yes	1	ISO885916
MULE_INTERNAL	Mule internal code	Multilingual Emacs	Yes	1-4	
SJIS	Shift JIS	Japanese	No	1-2	Mskanji, ShiftJIS, WIN932, Windows932
SHIFT_JIS_2004	Shift JIS, JIS X 0213	Japanese	No	1-2	
SQL_ASCII	unspecified (see text)	*any*	Yes	1	
UHC	Unified Hangul Code	Korean	No	1-2	WIN949, Windows949
UTF8	Unicode, 8-bit	*all*	Yes	1-4	Unicode
WIN866	Windows CP866	Cyrillic	Yes	1	ALT
WIN874	Windows CP874	Thai	Yes	1	
WIN1250	Windows CP1250	Central European	Yes	1	
WIN1251	Windows CP1251	Cyrillic	Yes	1	WIN
WIN1252	Windows CP1252	Western European	Yes	1	
WIN1253	Windows CP1253	Greek	Yes	1	
WIN1254	Windows CP1254	Turkish	Yes	1	
WIN1255	Windows CP1255	Hebrew	Yes	1	
WIN1256	Windows CP1256	Arabic	Yes	1	
WIN1257	Windows CP1257	Baltic	Yes	1	

Name	Description	Language	Server?	Bytes/Char	Aliases
WIN1258	Windows CP1258	Vietnamese	Yes	1	ABC, TCVN, TCVN5712, VSCII

Not all client APIs support all the listed character sets. For example, the PostgreSQL JDBC driver does not support MULE_INTERNAL, LATIN6, LATIN8, and LATIN10.

The SQL_ASCII setting behaves considerably differently from the other settings. When the server character set is SQL_ASCII, the server interprets byte values 0-127 according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. No encoding conversion will be done when the setting is SQL_ASCII. Thus, this setting is not so much a declaration that a specific encoding is in use, as a declaration of ignorance about the encoding. In most cases, if you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting because PostgreSQL will be unable to help you by converting or validating non-ASCII characters.

22.3.2. Setting the Character Set

initdb defines the default character set (encoding) for a PostgreSQL cluster. For example,

```
initdb -E EUC_JP
```

sets the default character set to EUC_JP (Extended Unix Code for Japanese). You can use --encoding instead of -E if you prefer longer option strings. If no -E or --encoding option is given, initdb attempts to determine the appropriate encoding to use based on the specified or default locale.

You can specify a non-default encoding at database creation time, provided that the encoding is compatible with the selected locale:

```
createdb -E EUC_KR -T template0 --lc-collate=ko_KR.euckr --lc-ctype=ko_KR.euckr korean
```

This will create a database named korean that uses the character set EUC_KR, and locale ko_KR. Another way to accomplish this is to use this SQL command:

```
CREATE DATABASE korean WITH ENCODING 'EUC_KR' LC_COLLATE='ko_KR.euckr' LC_CTYPE='ko_KR.e
```

Notice that the above commands specify copying the template0 database. When copying any other database, the encoding and locale settings cannot be changed from those of the source database, because that might result in corrupt data. For more information see Section 21.3.

The encoding for a database is stored in the system catalog pg_database. You can see it by using the psql -l option or the \l command.

```
$ psql -l
                                        List of databases
   Name    |  Owner   | Encoding  |  Collation  |    Ctype    |          Access Privileg
-----------+----------+-----------+-------------+-------------+--------------------------
 clocaledb | hlinnaka | SQL_ASCII | C           | C           |
 englishdb | hlinnaka | UTF8      | en_GB.UTF8  | en_GB.UTF8  |
 japanese  | hlinnaka | UTF8      | ja_JP.UTF8  | ja_JP.UTF8  |
 korean    | hlinnaka | EUC_KR    | ko_KR.euckr | ko_KR.euckr |
 postgres  | hlinnaka | UTF8      | fi_FI.UTF8  | fi_FI.UTF8  |
 template0 | hlinnaka | UTF8      | fi_FI.UTF8  | fi_FI.UTF8  | {=c/hlinnaka,hlinnaka=CT
 template1 | hlinnaka | UTF8      | fi_FI.UTF8  | fi_FI.UTF8  | {=c/hlinnaka,hlinnaka=CT
```

```
(7 rows)
```

Important: On most modern operating systems, PostgreSQL can determine which character set is implied by the LC_CTYPE setting, and it will enforce that only the matching database encoding is used. On older systems it is your responsibility to ensure that you use the encoding expected by the locale you have selected. A mistake in this area is likely to lead to strange behavior of locale-dependent operations such as sorting.

PostgreSQL will allow superusers to create databases with SQL_ASCII encoding even when LC_CTYPE is not C or POSIX. As noted above, SQL_ASCII does not enforce that the data stored in the database has any particular encoding, and so this choice poses risks of locale-dependent misbehavior. Using this combination of settings is deprecated and may someday be forbidden altogether.

22.3.3. Automatic Character Set Conversion Between Server and Client

PostgreSQL supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the pg_conversion system catalog. PostgreSQL comes with some predefined conversions, as shown in Table 22-2. You can create a new conversion using the SQL command CREATE CONVERSION.

Table 22-2. Client/Server Character Set Conversions

Server Character Set	Available Client Character Sets
BIG5	*not supported as a server encoding*
EUC_CN	*EUC_CN*, MULE_INTERNAL, UTF8
EUC_JP	*EUC_JP*, MULE_INTERNAL, SJIS, UTF8
EUC_KR	*EUC_KR*, MULE_INTERNAL, UTF8
EUC_TW	*EUC_TW*, BIG5, MULE_INTERNAL, UTF8
GB18030	*not supported as a server encoding*
GBK	*not supported as a server encoding*
ISO_8859_5	*ISO_8859_5*, KOI8R, MULE_INTERNAL, UTF8, WIN866, WIN1251
ISO_8859_6	*ISO_8859_6*, UTF8
ISO_8859_7	*ISO_8859_7*, UTF8
ISO_8859_8	*ISO_8859_8*, UTF8
JOHAB	*JOHAB*, UTF8
KOI8R	*KOI8R*, ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251
KOI8U	*KOI8U*, UTF8
LATIN1	*LATIN1*, MULE_INTERNAL, UTF8
LATIN2	*LATIN2*, MULE_INTERNAL, UTF8, WIN1250
LATIN3	*LATIN3*, MULE_INTERNAL, UTF8

Server Character Set	Available Client Character Sets
LATIN4	*LATIN4*, MULE_INTERNAL, UTF8
LATIN5	*LATIN5*, UTF8
LATIN6	*LATIN6*, UTF8
LATIN7	*LATIN7*, UTF8
LATIN8	*LATIN8*, UTF8
LATIN9	*LATIN9*, UTF8
LATIN10	*LATIN10*, UTF8
MULE_INTERNAL	*MULE_INTERNAL*, BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8R, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251
SJIS	*not supported as a server encoding*
SQL_ASCII	*any (no conversion will be performed)*
UHC	*not supported as a server encoding*
UTF8	*all supported encodings*
WIN866	*WIN866*, ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN1251
WIN874	*WIN874*, UTF8
WIN1250	*WIN1250*, LATIN2, MULE_INTERNAL, UTF8
WIN1251	*WIN1251*, ISO_8859_5, KOI8R, MULE_INTERNAL, UTF8, WIN866
WIN1252	*WIN1252*, UTF8
WIN1253	*WIN1253*, UTF8
WIN1254	*WIN1254*, UTF8
WIN1255	*WIN1255*, UTF8
WIN1256	*WIN1256*, UTF8
WIN1257	*WIN1257*, UTF8
WIN1258	*WIN1258*, UTF8

To enable automatic character set conversion, you have to tell PostgreSQL the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in psql. `\encoding` allows you to change client encoding on the fly. For example, to change the encoding to `SJIS`, type:

  ```
  \encoding SJIS
  ```

- libpq (Section 31.10) has functions to control the client encoding.

- Using `SET client_encoding TO`. Setting the client encoding can be done with this SQL command:

  ```
  SET CLIENT_ENCODING TO 'value';
  ```

  Also you can use the standard SQL syntax `SET NAMES` for this purpose:

  ```
  SET NAMES 'value';
  ```

  To query the current client encoding:

```
SHOW client_encoding;
```

To return to the default encoding:

```
RESET client_encoding;
```

- Using `PGCLIENTENCODING`. If the environment variable `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)
- Using the configuration variable client_encoding. If the `client_encoding` variable is set, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible — suppose you chose `EUC_JP` for the server and `LATIN1` for the client, and some Japanese characters are returned that do not have a representation in `LATIN1` — an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is disabled, regardless of the server's character set. Just as for the server, use of `SQL_ASCII` is unwise unless you are working with all-ASCII data.

22.3.4. Further Reading

These are good sources to start learning about various kinds of encoding systems.

CJKV Information Processing: Chinese, Japanese, Korean & Vietnamese Computing

Contains detailed explanations of `EUC_JP`, `EUC_CN`, `EUC_KR`, `EUC_TW`.

http://www.unicode.org/

The web site of the Unicode Consortium.

RFC 3629

UTF-8 (8-bit UCS/Unicode Transformation Format) is defined here.

Chapter 23. Routine Database Maintenance Tasks

PostgreSQL, like any database software, requires that certain tasks be performed regularly to achieve optimum performance. The tasks discussed here are *required*, but they are repetitive in nature and can easily be automated using standard tools such as cron scripts or Windows' Task Scheduler. It is the database administrator's responsibility to set up appropriate scripts, and to check that they execute successfully.

One obvious maintenance task is the creation of backup copies of the data on a regular schedule. Without a recent backup, you have no chance of recovery after a catastrophe (disk failure, fire, mistakenly dropping a critical table, etc.). The backup and recovery mechanisms available in PostgreSQL are discussed at length in Chapter 24.

The other main category of maintenance task is periodic "vacuuming" of the database. This activity is discussed in Section 23.1. Closely related to this is updating the statistics that will be used by the query planner, as discussed in Section 23.1.3.

Another task that might need periodic attention is log file management. This is discussed in Section 23.3.

check_postgres[1] is available for monitoring database health and reporting unusual conditions. check_postgres integrates with Nagios and MRTG, but can be run standalone too.

PostgreSQL is low-maintenance compared to some other database management systems. Nonetheless, appropriate attention to these tasks will go far towards ensuring a pleasant and productive experience with the system.

23.1. Routine Vacuuming

PostgreSQL databases require periodic maintenance known as *vacuuming*. For many installations, it is sufficient to let vacuuming be performed by the *autovacuum daemon*, which is described in Section 23.1.6. You might need to adjust the autovacuuming parameters described there to obtain best results for your situation. Some database administrators will want to supplement or replace the daemon's activities with manually-managed `VACUUM` commands, which typically are executed according to a schedule by cron or Task Scheduler scripts. To set up manually-managed vacuuming properly, it is essential to understand the issues discussed in the next few subsections. Administrators who rely on autovacuuming may still wish to skim this material to help them understand and adjust autovacuuming.

23.1.1. Vacuuming Basics

PostgreSQL's VACUUM command has to process each table on a regular basis for several reasons:

1. To recover or reuse disk space occupied by updated or deleted rows.
2. To update data statistics used by the PostgreSQL query planner.
3. To update the visibility map, which speeds up index-only scans.

1. http://bucardo.org/wiki/Check_postgres

4. To protect against loss of very old data due to *transaction ID wraparound* or *multixact ID wraparound*.

Each of these reasons dictates performing VACUUM operations of varying frequency and scope, as explained in the following subsections.

There are two variants of VACUUM: standard VACUUM and VACUUM FULL. VACUUM FULL can reclaim more disk space but runs much more slowly. Also, the standard form of VACUUM can run in parallel with production database operations. (Commands such as SELECT, INSERT, UPDATE, and DELETE will continue to function normally, though you will not be able to modify the definition of a table with commands such as ALTER TABLE while it is being vacuumed.) VACUUM FULL requires exclusive lock on the table it is working on, and therefore cannot be done in parallel with other use of the table. Generally, therefore, administrators should strive to use standard VACUUM and avoid VACUUM FULL.

VACUUM creates a substantial amount of I/O traffic, which can cause poor performance for other active sessions. There are configuration parameters that can be adjusted to reduce the performance impact of background vacuuming — see Section 18.4.4.

23.1.2. Recovering Disk Space

In PostgreSQL, an UPDATE or DELETE of a row does not immediately remove the old version of the row. This approach is necessary to gain the benefits of multiversion concurrency control (MVCC, see Chapter 13): the row version must not be deleted while it is still potentially visible to other transactions. But eventually, an outdated or deleted row version is no longer of interest to any transaction. The space it occupies must then be reclaimed for reuse by new rows, to avoid unbounded growth of disk space requirements. This is done by running VACUUM.

The standard form of VACUUM removes dead row versions in tables and indexes and marks the space available for future reuse. However, it will not return the space to the operating system, except in the special case where one or more pages at the end of a table become entirely free and an exclusive table lock can be easily obtained. In contrast, VACUUM FULL actively compacts tables by writing a complete new version of the table file with no dead space. This minimizes the size of the table, but can take a long time. It also requires extra disk space for the new copy of the table, until the operation completes.

The usual goal of routine vacuuming is to do standard VACUUMs often enough to avoid needing VACUUM FULL. The autovacuum daemon attempts to work this way, and in fact will never issue VACUUM FULL. In this approach, the idea is not to keep tables at their minimum size, but to maintain steady-state usage of disk space: each table occupies space equivalent to its minimum size plus however much space gets used up between vacuumings. Although VACUUM FULL can be used to shrink a table back to its minimum size and return the disk space to the operating system, there is not much point in this if the table will just grow again in the future. Thus, moderately-frequent standard VACUUM runs are a better approach than infrequent VACUUM FULL runs for maintaining heavily-updated tables.

Some administrators prefer to schedule vacuuming themselves, for example doing all the work at night when load is low. The difficulty with doing vacuuming according to a fixed schedule is that if a table has an unexpected spike in update activity, it may get bloated to the point that VACUUM FULL is really necessary to reclaim space. Using the autovacuum daemon alleviates this problem, since the daemon schedules vacuuming dynamically in response to update activity. It is unwise to disable the daemon completely unless you have an extremely predictable workload. One possible compromise is to set the daemon's parameters so that it will only react to unusually heavy update activity, thus keeping things from getting out of hand, while scheduled VACUUMs are expected to do the bulk of the work when the load is typical.

For those not using autovacuum, a typical approach is to schedule a database-wide VACUUM once a day during a low-usage period, supplemented by more frequent vacuuming of heavily-updated tables as necessary. (Some installations with extremely high update rates vacuum their busiest tables as often as once every few minutes.) If you have multiple databases in a cluster, don't forget to VACUUM each one; the program vacuumdb might be helpful.

> **Tip:** Plain VACUUM may not be satisfactory when a table contains large numbers of dead row versions as a result of massive update or delete activity. If you have such a table and you need to reclaim the excess disk space it occupies, you will need to use VACUUM FULL, or alternatively CLUSTER or one of the table-rewriting variants of ALTER TABLE. These commands rewrite an entire new copy of the table and build new indexes for it. All these options require exclusive lock. Note that they also temporarily use extra disk space approximately equal to the size of the table, since the old copies of the table and indexes can't be released until the new ones are complete.

> **Tip:** If you have a table whose entire contents are deleted on a periodic basis, consider doing it with TRUNCATE rather than using DELETE followed by VACUUM. TRUNCATE removes the entire content of the table immediately, without requiring a subsequent VACUUM or VACUUM FULL to reclaim the now-unused disk space. The disadvantage is that strict MVCC semantics are violated.

23.1.3. Updating Planner Statistics

The PostgreSQL query planner relies on statistical information about the contents of tables in order to generate good plans for queries. These statistics are gathered by the ANALYZE command, which can be invoked by itself or as an optional step in VACUUM. It is important to have reasonably accurate statistics, otherwise poor choices of plans might degrade database performance.

The autovacuum daemon, if enabled, will automatically issue ANALYZE commands whenever the content of a table has changed sufficiently. However, administrators might prefer to rely on manually-scheduled ANALYZE operations, particularly if it is known that update activity on a table will not affect the statistics of "interesting" columns. The daemon schedules ANALYZE strictly as a function of the number of rows inserted or updated; it has no knowledge of whether that will lead to meaningful statistical changes.

As with vacuuming for space recovery, frequent updates of statistics are more useful for heavily-updated tables than for seldom-updated ones. But even for a heavily-updated table, there might be no need for statistics updates if the statistical distribution of the data is not changing much. A simple rule of thumb is to think about how much the minimum and maximum values of the columns in the table change. For example, a timestamp column that contains the time of row update will have a constantly-increasing maximum value as rows are added and updated; such a column will probably need more frequent statistics updates than, say, a column containing URLs for pages accessed on a website. The URL column might receive changes just as often, but the statistical distribution of its values probably changes relatively slowly.

It is possible to run ANALYZE on specific tables and even just specific columns of a table, so the flexibility exists to update some statistics more frequently than others if your application requires it. In practice, however, it is usually best to just analyze the entire database, because it is a fast operation. ANALYZE uses a statistically random sampling of the rows of a table rather than reading every single row.

Tip: Although per-column tweaking of ANALYZE frequency might not be very productive, you might find it worthwhile to do per-column adjustment of the level of detail of the statistics collected by ANALYZE. Columns that are heavily used in WHERE clauses and have highly irregular data distributions might require a finer-grain data histogram than other columns. See ALTER TABLE SET STATISTICS, or change the database-wide default using the default_statistics_target configuration parameter.

Also, by default there is limited information available about the selectivity of functions. However, if you create an expression index that uses a function call, useful statistics will be gathered about the function, which can greatly improve query plans that use the expression index.

Tip: The autovacuum daemon does not issue ANALYZE commands for foreign tables, since it has no means of determining how often that might be useful. If your queries require statistics on foreign tables for proper planning, it's a good idea to run manually-managed ANALYZE commands on those tables on a suitable schedule.

23.1.4. Updating The Visibility Map

Vacuum maintains a visibility map for each table to keep track of which pages contain only tuples that are known to be visible to all active transactions (and all future transactions, until the page is again modified). This has two purposes. First, vacuum itself can skip such pages on the next run, since there is nothing to clean up.

Second, it allows PostgreSQL to answer some queries using only the index, without reference to the underlying table. Since PostgreSQL indexes don't contain tuple visibility information, a normal index scan fetches the heap tuple for each matching index entry, to check whether it should be seen by the current transaction. An *index-only scan*, on the other hand, checks the visibility map first. If it's known that all tuples on the page are visible, the heap fetch can be skipped. This is most noticeable on large data sets where the visibility map can prevent disk accesses. The visibility map is vastly smaller than the heap, so it can easily be cached even when the heap is very large.

23.1.5. Preventing Transaction ID Wraparound Failures

PostgreSQL's MVCC transaction semantics depend on being able to compare transaction ID (XID) numbers: a row version with an insertion XID greater than the current transaction's XID is "in the future" and should not be visible to the current transaction. But since transaction IDs have limited size (32 bits) a cluster that runs for a long time (more than 4 billion transactions) would suffer *transaction ID wraparound*: the XID counter wraps around to zero, and all of a sudden transactions that were in the past appear to be in the future — which means their output become invisible. In short, catastrophic data loss. (Actually the data is still there, but that's cold comfort if you cannot get at it.) To avoid this, it is necessary to vacuum every table in every database at least once every two billion transactions.

The reason that periodic vacuuming solves the problem is that VACUUM will mark rows as *frozen*, indicating that they were inserted by a transaction which committed sufficiently far in the past that the effects of the inserting transaction is certain to be visible, from an MVCC perspective, to all current and future transactions. PostgreSQL reserves a special XID, FrozenTransactionId, which does not follow the normal XID comparison rules and is always considered older than every normal XID. Normal XIDs are compared using modulo-2^{32} arithmetic. This means that for every normal XID, there are two billion XIDs that are "older" and two billion that are "newer"; another way to say it

is that the normal XID space is circular with no endpoint. Therefore, once a row version has been created with a particular normal XID, the row version will appear to be "in the past" for the next two billion transactions, no matter which normal XID we are talking about. If the row version still exists after more than two billion transactions, it will suddenly appear to be in the future. To prevent this, frozen row versions are treated as if the inserting XID were `FrozenTransactionId`, so that they will appear to be "in the past" to all normal transactions regardless of wraparound issues, and so such row versions will be valid until deleted, no matter how long that is.

vacuum_freeze_min_age controls how old an XID value has to be before its row version will be frozen. Increasing this setting may avoid unnecessary work if the rows that would otherwise be frozen will soon be modified again, but decreasing this setting increases the number of transactions that can elapse before the table must be vacuumed again.

`VACUUM` normally skips pages that don't have any dead row versions, but those pages might still have row versions with old XID values. To ensure all old row versions have been frozen, a scan of the whole table is needed. vacuum_freeze_table_age controls when `VACUUM` does that: a whole table sweep is forced if the table hasn't been fully scanned for `vacuum_freeze_table_age` minus `vacuum_freeze_min_age` transactions. Setting it to 0 forces `VACUUM` to always scan all pages, effectively ignoring the visibility map.

The maximum time that a table can go unvacuumed is two billion transactions minus the `vacuum_freeze_min_age` value at the time `VACUUM` last scanned the whole table. If it were to go unvacuumed for longer than that, data loss could result. To ensure that this does not happen, autovacuum is invoked on any table that might contain unfrozen rows with XIDs older than the age specified by the configuration parameter autovacuum_freeze_max_age. (This will happen even if autovacuum is disabled.)

This implies that if a table is not otherwise vacuumed, autovacuum will be invoked on it approximately once every `autovacuum_freeze_max_age` minus `vacuum_freeze_min_age` transactions. For tables that are regularly vacuumed for space reclamation purposes, this is of little importance. However, for static tables (including tables that receive inserts, but no updates or deletes), there is no need to vacuum for space reclamation, so it can be useful to try to maximize the interval between forced autovacuums on very large static tables. Obviously one can do this either by increasing `autovacuum_freeze_max_age` or decreasing `vacuum_freeze_min_age`.

The effective maximum for `vacuum_freeze_table_age` is 0.95 * `autovacuum_freeze_max_age`; a setting higher than that will be capped to the maximum. A value higher than `autovacuum_freeze_max_age` wouldn't make sense because an anti-wraparound autovacuum would be triggered at that point anyway, and the 0.95 multiplier leaves some breathing room to run a manual `VACUUM` before that happens. As a rule of thumb, `vacuum_freeze_table_age` should be set to a value somewhat below `autovacuum_freeze_max_age`, leaving enough gap so that a regularly scheduled `VACUUM` or an autovacuum triggered by normal delete and update activity is run in that window. Setting it too close could lead to anti-wraparound autovacuums, even though the table was recently vacuumed to reclaim space, whereas lower values lead to more frequent whole-table scans.

The sole disadvantage of increasing `autovacuum_freeze_max_age` (and `vacuum_freeze_table_age` along with it) is that the `pg_clog` subdirectory of the database cluster will take more space, because it must store the commit status of all transactions back to the `autovacuum_freeze_max_age` horizon. The commit status uses two bits per transaction, so if `autovacuum_freeze_max_age` is set to its maximum allowed value of two billion, `pg_clog` can be expected to grow to about half a gigabyte. If this is trivial compared to your total database size, setting `autovacuum_freeze_max_age` to its maximum allowed value is recommended. Otherwise, set it depending on what you are willing to allow for `pg_clog` storage. (The default, 200 million transactions, translates to about 50MB of `pg_clog` storage.)

One disadvantage of decreasing vacuum_freeze_min_age is that it might cause VACUUM to do useless work: freezing a row version is a waste of time if the row is modified soon thereafter (causing it to acquire a new XID). So the setting should be large enough that rows are not frozen until they are unlikely to change any more.

To track the age of the oldest unfrozen XIDs in a database, VACUUM stores XID statistics in the system tables pg_class and pg_database. In particular, the relfrozenxid column of a table's pg_class row contains the freeze cutoff XID that was used by the last whole-table VACUUM for that table. All rows inserted by transactions with XIDs older than this cutoff XID are guaranteed to have been frozen. Similarly, the datfrozenxid column of a database's pg_database row is a lower bound on the unfrozen XIDs appearing in that database — it is just the minimum of the per-table relfrozenxid values within the database. A convenient way to examine this information is to execute queries such as:

```
SELECT c.oid::regclass as table_name,
       greatest(age(c.relfrozenxid),age(t.relfrozenxid)) as age
FROM pg_class c
LEFT JOIN pg_class t ON c.reltoastrelid = t.oid
WHERE c.relkind IN ('r', 'm');

SELECT datname, age(datfrozenxid) FROM pg_database;
```

The age column measures the number of transactions from the cutoff XID to the current transaction's XID.

VACUUM normally only scans pages that have been modified since the last vacuum, but relfrozenxid can only be advanced when the whole table is scanned. The whole table is scanned when relfrozenxid is more than vacuum_freeze_table_age transactions old, when VACUUM's FREEZE option is used, or when all pages happen to require vacuuming to remove dead row versions. When VACUUM scans the whole table, after it's finished age(relfrozenxid) should be a little more than the vacuum_freeze_min_age setting that was used (more by the number of transactions started since the VACUUM started). If no whole-table-scanning VACUUM is issued on the table until autovacuum_freeze_max_age is reached, an autovacuum will soon be forced for the table.

If for some reason autovacuum fails to clear old XIDs from a table, the system will begin to emit warning messages like this when the database's oldest XIDs reach ten million transactions from the wraparound point:

```
WARNING:  database "mydb" must be vacuumed within 177009986 transactions
HINT:  To avoid a database shutdown, execute a database-wide VACUUM in "mydb".
```

(A manual VACUUM should fix the problem, as suggested by the hint; but note that the VACUUM must be performed by a superuser, else it will fail to process system catalogs and thus not be able to advance the database's datfrozenxid.) If these warnings are ignored, the system will shut down and refuse to start any new transactions once there are fewer than 1 million transactions left until wraparound:

```
ERROR:  database is not accepting commands to avoid wraparound data loss in database "my
HINT:  Stop the postmaster and vacuum that database in single-user mode.
```

The 1-million-transaction safety margin exists to let the administrator recover without data loss, by manually executing the required VACUUM commands. However, since the system will not execute commands once it has gone into the safety shutdown mode, the only way to do this is to stop the server and start the server in single-user mode to execute VACUUM. The shutdown mode is not enforced in single-user mode. See the postgres reference page for details about using single-user mode.

23.1.5.1. Multixacts and Wraparound

Multixact IDs are used to support row locking by multiple transactions. Since there is only limited space in a tuple header to store lock information, that information is encoded as a "multiple transaction ID", or multixact ID for short, whenever there is more than one transaction concurrently locking a row. Information about which transaction IDs are included in any particular multixact ID is stored separately in the `pg_multixact` subdirectory, and only the multixact ID appears in the `xmax` field in the tuple header. Like transaction IDs, multixact IDs are implemented as a 32-bit counter and corresponding storage, all of which requires careful aging management, storage cleanup, and wraparound handling.

During a `VACUUM` table scan, either partial or of the whole table, any multixact ID older than vacuum_multixact_freeze_min_age is replaced by a different value, which can be the zero value, a single transaction ID, or a newer multixact ID. For each table, `pg_class.relminmxid` stores the oldest possible multixact ID still appearing in any tuple of that table. If this value is older than vacuum_multixact_freeze_table_age, a whole-table scan is forced. Whole-table `VACUUM` scans, regardless of what causes them, enable advancing the value for that table. Eventually, as all tables in all databases are scanned and their oldest multixact values are advanced, on-disk storage for older multixacts can be removed.

As a safety device, a whole-table vacuum scan will occur for any table whose multixact-age is greater than autovacuum_multixact_freeze_max_age. This will occur even if autovacuum is nominally disabled.

23.1.6. The Autovacuum Daemon

PostgreSQL has an optional but highly recommended feature called *autovacuum*, whose purpose is to automate the execution of `VACUUM` and `ANALYZE` commands. When enabled, autovacuum checks for tables that have had a large number of inserted, updated or deleted tuples. These checks use the statistics collection facility; therefore, autovacuum cannot be used unless track_counts is set to `true`. In the default configuration, autovacuuming is enabled and the related configuration parameters are appropriately set.

The "autovacuum daemon" actually consists of multiple processes. There is a persistent daemon process, called the *autovacuum launcher*, which is in charge of starting *autovacuum worker* processes for all databases. The launcher will distribute the work across time, attempting to start one worker within each database every autovacuum_naptime seconds. (Therefore, if the installation has *N* databases, a new worker will be launched every `autovacuum_naptime`/*N* seconds.) A maximum of autovacuum_max_workers worker processes are allowed to run at the same time. If there are more than `autovacuum_max_workers` databases to be processed, the next database will be processed as soon as the first worker finishes. Each worker process will check each table within its database and execute `VACUUM` and/or `ANALYZE` as needed. `log_autovacuum_min_duration` can be used to monitor autovacuum activity.

If several large tables all become eligible for vacuuming in a short amount of time, all autovacuum workers might become occupied with vacuuming those tables for a long period. This would result in other tables and databases not being vacuumed until a worker became available. There is no limit on how many workers might be in a single database, but workers do try to avoid repeating work that has already been done by other workers. Note that the number of running workers does not count towards max_connections or superuser_reserved_connections limits.

Tables whose `relfrozenxid` value is more than autovacuum_freeze_max_age transactions old are always vacuumed (this also applies to those tables whose freeze max age has been modified via

storage parameters; see below). Otherwise, if the number of tuples obsoleted since the last VACUUM exceeds the "vacuum threshold", the table is vacuumed. The vacuum threshold is defined as:

```
vacuum threshold = vacuum base threshold + vacuum scale factor * number of tuples
```

where the vacuum base threshold is autovacuum_vacuum_threshold, the vacuum scale factor is autovacuum_vacuum_scale_factor, and the number of tuples is pg_class.reltuples. The number of obsolete tuples is obtained from the statistics collector; it is a semi-accurate count updated by each UPDATE and DELETE operation. (It is only semi-accurate because some information might be lost under heavy load.) If the relfrozenxid value of the table is more than vacuum_freeze_table_age transactions old, the whole table is scanned to freeze old tuples and advance relfrozenxid, otherwise only pages that have been modified since the last vacuum are scanned.

For analyze, a similar condition is used: the threshold, defined as:

```
analyze threshold = analyze base threshold + analyze scale factor * number of tuples
```

is compared to the total number of tuples inserted, updated, or deleted since the last ANALYZE.

Temporary tables cannot be accessed by autovacuum. Therefore, appropriate vacuum and analyze operations should be performed via session SQL commands.

The default thresholds and scale factors are taken from postgresql.conf, but it is possible to override them on a table-by-table basis; see *Storage Parameters* for more information. If a setting has been changed via storage parameters, that value is used; otherwise the global settings are used. See Section 18.10 for more details on the global settings.

Besides the base threshold values and scale factors, there are six more autovacuum parameters that can be set for each table via storage parameters. The first parameter, autovacuum_enabled, can be set to false to instruct the autovacuum daemon to skip that particular table entirely. In this case autovacuum will only touch the table if it must do so to prevent transaction ID wraparound. Another two parameters, autovacuum_vacuum_cost_delay and autovacuum_vacuum_cost_limit, are used to set table-specific values for the cost-based vacuum delay feature (see Section 18.4.4). autovacuum_freeze_min_age, autovacuum_freeze_max_age and autovacuum_freeze_table_age are used to set values for vacuum_freeze_min_age, autovacuum_freeze_max_age and vacuum_freeze_table_age respectively.

When multiple workers are running, the cost delay parameters are "balanced" among all the running workers, so that the total I/O impact on the system is the same regardless of the number of workers actually running. However, any workers processing tables whose autovacuum_vacuum_cost_delay or autovacuum_vacuum_cost_limit have been set are not considered in the balancing algorithm.

23.2. Routine Reindexing

In some situations it is worthwhile to rebuild indexes periodically with the REINDEX command or a series of individual rebuilding steps.

B-tree index pages that have become completely empty are reclaimed for re-use. However, there is still a possibility of inefficient use of space: if all but a few index keys on a page have been deleted, the page remains allocated. Therefore, a usage pattern in which most, but not all, keys in each range are eventually deleted will see poor use of space. For such usage patterns, periodic reindexing is recommended.

The potential for bloat in non-B-tree indexes has not been well researched. It is a good idea to periodically monitor the index's physical size when using any non-B-tree index type.

Also, for B-tree indexes, a freshly-constructed index is slightly faster to access than one that has been updated many times because logically adjacent pages are usually also physically adjacent in a newly built index. (This consideration does not apply to non-B-tree indexes.) It might be worthwhile to reindex periodically just to improve access speed.

REINDEX can be used safely and easily in all cases. But since the command requires an exclusive table lock, it is often preferable to execute an index rebuild with a sequence of creation and replacement steps. Index types that support CREATE INDEX with the `CONCURRENTLY` option can instead be recreated that way. If that is successful and the resulting index is valid, the original index can then be replaced by the newly built one using a combination of ALTER INDEX and DROP INDEX. When an index is used to enforce uniqueness or other constraints, ALTER TABLE might be necessary to swap the existing constraint with one enforced by the new index. Review this alternate multi-step rebuild approach carefully before using it as there are limitations on which indexes can be reindexed this way, and errors must be handled.

23.3. Log File Maintenance

It is a good idea to save the database server's log output somewhere, rather than just discarding it via `/dev/null`. The log output is invaluable when diagnosing problems. However, the log output tends to be voluminous (especially at higher debug levels) so you won't want to save it indefinitely. You need to *rotate* the log files so that new log files are started and old ones removed after a reasonable period of time.

If you simply direct the stderr of `postgres` into a file, you will have log output, but the only way to truncate the log file is to stop and restart the server. This might be acceptable if you are using PostgreSQL in a development environment, but few production servers would find this behavior acceptable.

A better approach is to send the server's stderr output to some type of log rotation program. There is a built-in log rotation facility, which you can use by setting the configuration parameter `logging_collector` to `true` in `postgresql.conf`. The control parameters for this program are described in Section 18.8.1. You can also use this approach to capture the log data in machine readable CSV (comma-separated values) format.

Alternatively, you might prefer to use an external log rotation program if you have one that you are already using with other server software. For example, the rotatelogs tool included in the Apache distribution can be used with PostgreSQL. To do this, just pipe the server's stderr output to the desired program. If you start the server with `pg_ctl`, then stderr is already redirected to stdout, so you just need a pipe command, for example:

```
pg_ctl start | rotatelogs /var/log/pgsql_log 86400
```

Another production-grade approach to managing log output is to send it to syslog and let syslog deal with file rotation. To do this, set the configuration parameter `log_destination` to `syslog` (to log to syslog only) in `postgresql.conf`. Then you can send a `SIGHUP` signal to the syslog daemon whenever you want to force it to start writing a new log file. If you want to automate log rotation, the logrotate program can be configured to work with log files from syslog.

On many systems, however, syslog is not very reliable, particularly with large log messages; it might truncate or drop messages just when you need them the most. Also, on Linux, syslog will flush each message to disk, yielding poor performance. (You can use a "–" at the start of the file name in the syslog configuration file to disable syncing.)

Note that all the solutions described above take care of starting new log files at configurable intervals, but they do not handle deletion of old, no-longer-useful log files. You will probably want to set up a batch job to periodically delete old log files. Another possibility is to configure the rotation program so that old log files are overwritten cyclically.

pgBadger[2] is an external project that does sophisticated log file analysis. check_postgres[3] provides Nagios alerts when important messages appear in the log files, as well as detection of many other extraordinary conditions.

2. http://dalibo.github.io/pgbadger/
3. http://bucardo.org/wiki/Check_postgres

Chapter 24. Backup and Restore

As with everything that contains valuable data, PostgreSQL databases should be backed up regularly. While the procedure is essentially simple, it is important to have a clear understanding of the underlying techniques and assumptions.

There are three fundamentally different approaches to backing up PostgreSQL data:

- SQL dump
- File system level backup
- Continuous archiving

Each has its own strengths and weaknesses; each is discussed in turn in the following sections.

24.1. SQL Dump

The idea behind this dump method is to generate a file with SQL commands that, when fed back to the server, will recreate the database in the same state as it was at the time of the dump. PostgreSQL provides the utility program pg_dump for this purpose. The basic usage of this command is:

```
pg_dump dbname > outfile
```

As you see, pg_dump writes its result to the standard output. We will see below how this can be useful. While the above command creates a text file, pg_dump can create files in other formats that allow for parallism and more fine-grained control of object restoration.

pg_dump is a regular PostgreSQL client application (albeit a particularly clever one). This means that you can perform this backup procedure from any remote host that has access to the database. But remember that pg_dump does not operate with special permissions. In particular, it must have read access to all tables that you want to back up, so in order to back up the entire database you almost always have to run it as a database superuser. (If you do not have sufficient privileges to back up the entire database, you can still back up portions of the database to which you do have access using options such as `-n schema` or `-t table`.)

To specify which database server pg_dump should contact, use the command line options `-h host` and `-p port`. The default host is the local host or whatever your `PGHOST` environment variable specifies. Similarly, the default port is indicated by the `PGPORT` environment variable or, failing that, by the compiled-in default. (Conveniently, the server will normally have the same compiled-in default.)

Like any other PostgreSQL client application, pg_dump will by default connect with the database user name that is equal to the current operating system user name. To override this, either specify the `-U` option or set the environment variable `PGUSER`. Remember that pg_dump connections are subject to the normal client authentication mechanisms (which are described in Chapter 19).

An important advantage of pg_dump over the other backup methods described later is that pg_dump's output can generally be re-loaded into newer versions of PostgreSQL, whereas file-level backups and continuous archiving are both extremely server-version-specific. pg_dump is also the only method that will work when transferring a database to a different machine architecture, such as going from a 32-bit to a 64-bit server.

Dumps created by pg_dump are internally consistent, meaning, the dump represents a snapshot of the database at the time pg_dump began running. pg_dump does not block other operations on the database while it is working. (Exceptions are those operations that need to operate with an exclusive lock, such as most forms of `ALTER TABLE`.)

24.1.1. Restoring the Dump

Text files created by pg_dump are intended to be read in by the psql program. The general command form to restore a dump is

```
psql dbname < infile
```

where *infile* is the file output by the pg_dump command. The database *dbname* will not be created by this command, so you must create it yourself from `template0` before executing psql (e.g., with `createdb -T template0 dbname`). psql supports options similar to pg_dump for specifying the database server to connect to and the user name to use. See the psql reference page for more information. Non-text file dumps are restored using the pg_restore utility.

Before restoring an SQL dump, all the users who own objects or were granted permissions on objects in the dumped database must already exist. If they do not, the restore will fail to recreate the objects with the original ownership and/or permissions. (Sometimes this is what you want, but usually it is not.)

By default, the psql script will continue to execute after an SQL error is encountered. You might wish to run psql with the `ON_ERROR_STOP` variable set to alter that behavior and have psql exit with an exit status of 3 if an SQL error occurs:

```
psql --set ON_ERROR_STOP=on dbname < infile
```

Either way, you will only have a partially restored database. Alternatively, you can specify that the whole dump should be restored as a single transaction, so the restore is either fully completed or fully rolled back. This mode can be specified by passing the `-1` or `--single-transaction` command-line options to psql. When using this mode, be aware that even a minor error can rollback a restore that has already run for many hours. However, that might still be preferable to manually cleaning up a complex database after a partially restored dump.

The ability of pg_dump and psql to write to or read from pipes makes it possible to dump a database directly from one server to another, for example:

```
pg_dump -h host1 dbname | psql -h host2 dbname
```

> **Important:** The dumps produced by pg_dump are relative to `template0`. This means that any languages, procedures, etc. added via `template1` will also be dumped by pg_dump. As a result, when restoring, if you are using a customized `template1`, you must create the empty database from `template0`, as in the example above.

After restoring a backup, it is wise to run ANALYZE on each database so the query optimizer has useful statistics; see Section 23.1.3 and Section 23.1.6 for more information. For more advice on how to load large amounts of data into PostgreSQL efficiently, refer to Section 14.4.

24.1.2. Using pg_dumpall

pg_dump dumps only a single database at a time, and it does not dump information about roles or tablespaces (because those are cluster-wide rather than per-database). To support convenient dumping of the entire contents of a database cluster, the pg_dumpall program is provided. pg_dumpall backs

up each database in a given cluster, and also preserves cluster-wide data such as role and tablespace definitions. The basic usage of this command is:

```
pg_dumpall > outfile
```

The resulting dump can be restored with psql:

```
psql -f infile postgres
```

(Actually, you can specify any existing database name to start from, but if you are loading into an empty cluster then `postgres` should usually be used.) It is always necessary to have database superuser access when restoring a pg_dumpall dump, as that is required to restore the role and tablespace information. If you use tablespaces, make sure that the tablespace paths in the dump are appropriate for the new installation.

pg_dumpall works by emitting commands to re-create roles, tablespaces, and empty databases, then invoking pg_dump for each database. This means that while each database will be internally consistent, the snapshots of different databases are not sychronized.

Cluster-wide data can be dumped alone using the pg_dumpall `--globals-only` option. This is necessary to fully backup the cluster if running the pg_dump command on individual databases.

24.1.3. Handling Large Databases

Some operating systems have maximum file size limits that cause problems when creating large pg_dump output files. Fortunately, pg_dump can write to the standard output, so you can use standard Unix tools to work around this potential problem. There are several possible methods:

Use compressed dumps. You can use your favorite compression program, for example gzip:

```
pg_dump dbname | gzip > filename.gz
```

Reload with:

```
gunzip -c filename.gz | psql dbname
```

or:

```
cat filename.gz | gunzip | psql dbname
```

Use `split`. The `split` command allows you to split the output into smaller files that are acceptable in size to the underlying file system. For example, to make chunks of 1 megabyte:

```
pg_dump dbname | split -b 1m - filename
```

Reload with:

```
cat filename* | psql dbname
```

Use pg_dump's custom dump format. If PostgreSQL was built on a system with the zlib compression library installed, the custom dump format will compress data as it writes it to the output file. This will produce dump file sizes similar to using `gzip`, but it has the added advantage that tables can be restored selectively. The following command dumps a database using the custom dump format:

```
pg_dump -Fc dbname > filename
```

A custom-format dump is not a script for psql, but instead must be restored with pg_restore, for example:

```
pg_restore -d dbname filename
```

See the pg_dump and pg_restore reference pages for details.

For very large databases, you might need to combine `split` with one of the other two approaches.

Use pg_dump's parallel dump feature. To speed up the dump of a large database, you can use pg_dump's parallel mode. This will dump multiple tables at the same time. You can control the degree of parallelism with the `-j` parameter. Parallel dumps are only supported for the "directory" archive format.

```
pg_dump -j num -F d -f out.dir dbname
```

You can use `pg_restore -j` to restore a dump in parallel. This will work for any archive of either the "custom" or the "directory" archive mode, whether or not it has been created with `pg_dump -j`.

24.2. File System Level Backup

An alternative backup strategy is to directly copy the files that PostgreSQL uses to store the data in the database; Section 17.2 explains where these files are located. You can use whatever method you prefer for doing file system backups; for example:

```
tar -cf backup.tar /usr/local/pgsql/data
```

There are two restrictions, however, which make this method impractical, or at least inferior to the pg_dump method:

1. The database server *must* be shut down in order to get a usable backup. Half-way measures such as disallowing all connections will *not* work (in part because `tar` and similar tools do not take an atomic snapshot of the state of the file system, but also because of internal buffering within the server). Information about stopping the server can be found in Section 17.5. Needless to say, you also need to shut down the server before restoring the data.
2. If you have dug into the details of the file system layout of the database, you might be tempted to try to back up or restore only certain individual tables or databases from their respective files or directories. This will *not* work because the information contained in these files is not usable without the commit log files, `pg_clog/*`, which contain the commit status of all transactions. A table file is only usable with this information. Of course it is also impossible to restore only a table and the associated `pg_clog` data because that would render all other tables in the database cluster useless. So file system backups only work for complete backup and restoration of an entire database cluster.

An alternative file-system backup approach is to make a "consistent snapshot" of the data directory, if the file system supports that functionality (and you are willing to trust that it is implemented correctly). The typical procedure is to make a "frozen snapshot" of the volume containing the database, then copy the whole data directory (not just parts, see above) from the snapshot to a backup device, then release the frozen snapshot. This will work even while the database server is running. However, a backup

created in this way saves the database files in a state as if the database server was not properly shut down; therefore, when you start the database server on the backed-up data, it will think the previous server instance crashed and will replay the WAL log. This is not a problem; just be aware of it (and be sure to include the WAL files in your backup). You can perform a `CHECKPOINT` before taking the snapshot to reduce recovery time.

If your database is spread across multiple file systems, there might not be any way to obtain exactly-simultaneous frozen snapshots of all the volumes. For example, if your data files and WAL log are on different disks, or if tablespaces are on different file systems, it might not be possible to use snapshot backup because the snapshots *must* be simultaneous. Read your file system documentation very carefully before trusting the consistent-snapshot technique in such situations.

If simultaneous snapshots are not possible, one option is to shut down the database server long enough to establish all the frozen snapshots. Another option is to perform a continuous archiving base backup (Section 24.3.2) because such backups are immune to file system changes during the backup. This requires enabling continuous archiving just during the backup process; restore is done using continuous archive recovery (Section 24.3.4).

Another option is to use rsync to perform a file system backup. This is done by first running rsync while the database server is running, then shutting down the database server just long enough to do a second rsync. The second rsync will be much quicker than the first, because it has relatively little data to transfer, and the end result will be consistent because the server was down. This method allows a file system backup to be performed with minimal downtime.

Note that a file system backup will typically be larger than an SQL dump. (pg_dump does not need to dump the contents of indexes for example, just the commands to recreate them.) However, taking a file system backup might be faster.

24.3. Continuous Archiving and Point-in-Time Recovery (PITR)

At all times, PostgreSQL maintains a *write ahead log* (WAL) in the `pg_xlog/` subdirectory of the cluster's data directory. The log records every change made to the database's data files. This log exists primarily for crash-safety purposes: if the system crashes, the database can be restored to consistency by "replaying" the log entries made since the last checkpoint. However, the existence of the log makes it possible to use a third strategy for backing up databases: we can combine a file-system-level backup with backup of the WAL files. If recovery is needed, we restore the file system backup and then replay from the backed-up WAL files to bring the system to a current state. This approach is more complex to administer than either of the previous approaches, but it has some significant benefits:

- We do not need a perfectly consistent file system backup as the starting point. Any internal inconsistency in the backup will be corrected by log replay (this is not significantly different from what happens during crash recovery). So we do not need a file system snapshot capability, just tar or a similar archiving tool.
- Since we can combine an indefinitely long sequence of WAL files for replay, continuous backup can be achieved simply by continuing to archive the WAL files. This is particularly valuable for large databases, where it might not be convenient to take a full backup frequently.
- It is not necessary to replay the WAL entries all the way to the end. We could stop the replay at any point and have a consistent snapshot of the database as it was at that time. Thus, this technique

supports *point-in-time recovery*: it is possible to restore the database to its state at any time since your base backup was taken.

- If we continuously feed the series of WAL files to another machine that has been loaded with the same base backup file, we have a *warm standby* system: at any point we can bring up the second machine and it will have a nearly-current copy of the database.

> **Note:** pg_dump and pg_dumpall do not produce file-system-level backups and cannot be used as part of a continuous-archiving solution. Such dumps are *logical* and do not contain enough information to be used by WAL replay.

As with the plain file-system-backup technique, this method can only support restoration of an entire database cluster, not a subset. Also, it requires a lot of archival storage: the base backup might be bulky, and a busy system will generate many megabytes of WAL traffic that have to be archived. Still, it is the preferred backup technique in many situations where high reliability is needed.

To recover successfully using continuous archiving (also called "online backup" by many database vendors), you need a continuous sequence of archived WAL files that extends back at least as far as the start time of your backup. So to get started, you should set up and test your procedure for archiving WAL files *before* you take your first base backup. Accordingly, we first discuss the mechanics of archiving WAL files.

24.3.1. Setting Up WAL Archiving

In an abstract sense, a running PostgreSQL system produces an indefinitely long sequence of WAL records. The system physically divides this sequence into WAL *segment files*, which are normally 16MB apiece (although the segment size can be altered when building PostgreSQL). The segment files are given numeric names that reflect their position in the abstract WAL sequence. When not using WAL archiving, the system normally creates just a few segment files and then "recycles" them by renaming no-longer-needed segment files to higher segment numbers. It's assumed that segment files whose contents precede the checkpoint-before-last are no longer of interest and can be recycled.

When archiving WAL data, we need to capture the contents of each segment file once it is filled, and save that data somewhere before the segment file is recycled for reuse. Depending on the application and the available hardware, there could be many different ways of "saving the data somewhere": we could copy the segment files to an NFS-mounted directory on another machine, write them onto a tape drive (ensuring that you have a way of identifying the original name of each file), or batch them together and burn them onto CDs, or something else entirely. To provide the database administrator with flexibility, PostgreSQL tries not to make any assumptions about how the archiving will be done. Instead, PostgreSQL lets the administrator specify a shell command to be executed to copy a completed segment file to wherever it needs to go. The command could be as simple as a `cp`, or it could invoke a complex shell script — it's all up to you.

To enable WAL archiving, set the wal_level configuration parameter to `archive` or higher, archive_mode to `on`, and specify the shell command to use in the archive_command configuration parameter. In practice these settings will always be placed in the `postgresql.conf` file. In `archive_command`, `%p` is replaced by the path name of the file to archive, while `%f` is replaced by only the file name. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Use `%%` if you need to embed an actual `%` character in the command. The simplest useful command is something like:

```
archive_command = 'test ! -f /mnt/server/archivedir/%f && cp %p /mnt/server/archivedir/%
archive_command = 'copy "%p" "C:\\server\\archivedir\\%f"'  # Windows
```

which will copy archivable WAL segments to the directory `/mnt/server/archivedir`. (This is an example, not a recommendation, and might not work on all platforms.) After the `%p` and `%f` parameters have been replaced, the actual command executed might look like this:

```
test ! -f /mnt/server/archivedir/000000010000000A900000065 && cp pg_xlog/000000010000000A9
```

A similar command will be generated for each new file to be archived.

The archive command will be executed under the ownership of the same user that the PostgreSQL server is running as. Since the series of WAL files being archived contains effectively everything in your database, you will want to be sure that the archived data is protected from prying eyes; for example, archive into a directory that does not have group or world read access.

It is important that the archive command return zero exit status if and only if it succeeds. Upon getting a zero result, PostgreSQL will assume that the file has been successfully archived, and will remove or recycle it. However, a nonzero status tells PostgreSQL that the file was not archived; it will try again periodically until it succeeds.

The archive command should generally be designed to refuse to overwrite any pre-existing archive file. This is an important safety feature to preserve the integrity of your archive in case of administrator error (such as sending the output of two different servers to the same archive directory).

It is advisable to test your proposed archive command to ensure that it indeed does not overwrite an existing file, *and that it returns nonzero status in this case*. The example command above for Unix ensures this by including a separate `test` step. On some Unix platforms, `cp` has switches such as `-i` that can be used to do the same thing less verbosely, but you should not rely on these without verifying that the right exit status is returned. (In particular, GNU `cp` will return status zero when `-i` is used and the target file already exists, which is *not* the desired behavior.)

While designing your archiving setup, consider what will happen if the archive command fails repeatedly because some aspect requires operator intervention or the archive runs out of space. For example, this could occur if you write to tape without an autochanger; when the tape fills, nothing further can be archived until the tape is swapped. You should ensure that any error condition or request to a human operator is reported appropriately so that the situation can be resolved reasonably quickly. The `pg_xlog/` directory will continue to fill with WAL segment files until the situation is resolved. (If the file system containing `pg_xlog/` fills up, PostgreSQL will do a PANIC shutdown. No committed transactions will be lost, but the database will remain offline until you free some space.)

The speed of the archiving command is unimportant as long as it can keep up with the average rate at which your server generates WAL data. Normal operation continues even if the archiving process falls a little behind. If archiving falls significantly behind, this will increase the amount of data that would be lost in the event of a disaster. It will also mean that the `pg_xlog/` directory will contain large numbers of not-yet-archived segment files, which could eventually exceed available disk space. You are advised to monitor the archiving process to ensure that it is working as you intend.

In writing your archive command, you should assume that the file names to be archived can be up to 64 characters long and can contain any combination of ASCII letters, digits, and dots. It is not necessary to preserve the original relative path (`%p`) but it is necessary to preserve the file name (`%f`).

Note that although WAL archiving will allow you to restore any modifications made to the data in your PostgreSQL database, it will not restore changes made to configuration files (that is, `postgresql.conf`, `pg_hba.conf` and `pg_ident.conf`), since those are edited manually rather than through SQL operations. You might wish to keep the configuration files in a location that will

be backed up by your regular file system backup procedures. See Section 18.2 for how to relocate the configuration files.

The archive command is only invoked on completed WAL segments. Hence, if your server generates only little WAL traffic (or has slack periods where it does so), there could be a long delay between the completion of a transaction and its safe recording in archive storage. To put a limit on how old unarchived data can be, you can set archive_timeout to force the server to switch to a new WAL segment file at least that often. Note that archived files that are archived early due to a forced switch are still the same length as completely full files. It is therefore unwise to set a very short `archive_timeout` — it will bloat your archive storage. `archive_timeout` settings of a minute or so are usually reasonable.

Also, you can force a segment switch manually with `pg_switch_xlog` if you want to ensure that a just-finished transaction is archived as soon as possible. Other utility functions related to WAL management are listed in Table 9-65.

When `wal_level` is `minimal` some SQL commands are optimized to avoid WAL logging, as described in Section 14.4.7. If archiving or streaming replication were turned on during execution of one of these statements, WAL would not contain enough information for archive recovery. (Crash recovery is unaffected.) For this reason, `wal_level` can only be changed at server start. However, `archive_command` can be changed with a configuration file reload. If you wish to temporarily stop archiving, one way to do it is to set `archive_command` to the empty string (''). This will cause WAL files to accumulate in `pg_xlog/` until a working `archive_command` is re-established.

24.3.2. Making a Base Backup

The easiest way to perform a base backup is to use the pg_basebackup tool. It can create a base backup either as regular files or as a tar archive. If more flexibility than pg_basebackup can provide is required, you can also make a base backup using the low level API (see Section 24.3.3).

It is not necessary to be concerned about the amount of time it takes to make a base backup. However, if you normally run the server with `full_page_writes` disabled, you might notice a drop in performance while the backup runs since `full_page_writes` is effectively forced on during backup mode.

To make use of the backup, you will need to keep all the WAL segment files generated during and after the file system backup. To aid you in doing this, the base backup process creates a *backup history file* that is immediately stored into the WAL archive area. This file is named after the first WAL segment file that you need for the file system backup. For example, if the starting WAL file is `000000010000123400000055CD` the backup history file will be named something like `000000010000123400000055CD.007C9330.backup`. (The second part of the file name stands for an exact position within the WAL file, and can ordinarily be ignored.) Once you have safely archived the file system backup and the WAL segment files used during the backup (as specified in the backup history file), all archived WAL segments with names numerically less are no longer needed to recover the file system backup and can be deleted. However, you should consider keeping several backup sets to be absolutely certain that you can recover your data.

The backup history file is just a small text file. It contains the label string you gave to pg_basebackup, as well as the starting and ending times and WAL segments of the backup. If you used the label to identify the associated dump file, then the archived history file is enough to tell you which dump file to restore.

Since you have to keep around all the archived WAL files back to your last base backup, the interval between base backups should usually be chosen based on how much storage you want to expend on archived WAL files. You should also consider how long you are prepared to spend recovering, if

recovery should be necessary — the system will have to replay all those WAL segments, and that could take awhile if it has been a long time since the last base backup.

24.3.3. Making a Base Backup Using the Low Level API

The procedure for making a base backup using the low level APIs contains a few more steps than the pg_basebackup method, but is relatively simple. It is very important that these steps are executed in sequence, and that the success of a step is verified before proceeding to the next step.

1. Ensure that WAL archiving is enabled and working.
2. Connect to the database as a superuser and issue the command:

   ```
   SELECT pg_start_backup('label');
   ```

   where `label` is any string you want to use to uniquely identify this backup operation. (One good practice is to use the full path where you intend to put the backup dump file.) `pg_start_backup` creates a *backup label* file, called `backup_label`, in the cluster directory with information about your backup, including the start time and label string. The file is critical to the integrity of the backup, should you need to restore from it.

   It does not matter which database within the cluster you connect to to issue this command. You can ignore the result returned by the function; but if it reports an error, deal with that before proceeding.

   By default, `pg_start_backup` can take a long time to finish. This is because it performs a checkpoint, and the I/O required for the checkpoint will be spread out over a significant period of time, by default half your inter-checkpoint interval (see the configuration parameter checkpoint_completion_target). This is usually what you want, because it minimizes the impact on query processing. If you want to start the backup as soon as possible, use:

   ```
   SELECT pg_start_backup('label', true);
   ```

   This forces the checkpoint to be done as quickly as possible.
3. Perform the backup, using any convenient file-system-backup tool such as tar or cpio (not pg_dump or pg_dumpall). It is neither necessary nor desirable to stop normal operation of the database while you do this.
4. Again connect to the database as a superuser, and issue the command:

   ```
   SELECT pg_stop_backup();
   ```

   This terminates the backup mode and performs an automatic switch to the next WAL segment. The reason for the switch is to arrange for the last WAL segment file written during the backup interval to be ready to archive.
5. Once the WAL segment files active during the backup are archived, you are done. The file identified by `pg_stop_backup`'s result is the last segment that is required to form a complete set of backup files. If `archive_mode` is enabled, `pg_stop_backup` does not return until the last segment has been archived. Archiving of these files happens automatically since you have already configured `archive_command`. In most cases this happens quickly, but you are advised to monitor your archive system to ensure there are no delays. If the archive process has fallen behind because of failures of the archive command, it will keep retrying until the archive succeeds and the backup is complete. If you wish to place a time limit on the execution of `pg_stop_backup`, set an appropriate `statement_timeout` value.

Some file system backup tools emit warnings or errors if the files they are trying to copy change while the copy proceeds. When taking a base backup of an active database, this situation is normal and not an error. However, you need to ensure that you can distinguish complaints of this sort from real errors. For example, some versions of rsync return a separate exit code for "vanished source files", and you can write a driver script to accept this exit code as a non-error case. Also, some versions of GNU tar return an error code indistinguishable from a fatal error if a file was truncated while tar was copying it. Fortunately, GNU tar versions 1.16 and later exit with 1 if a file was changed during the backup, and 2 for other errors. With GNU tar version 1.23 and later, you can use the warning options `--warning=no-file-changed --warning=no-file-removed` to hide the related warning messages.

Be certain that your backup dump includes all of the files under the database cluster directory (e.g., `/usr/local/pgsql/data`). If you are using tablespaces that do not reside underneath this directory, be careful to include them as well (and be sure that your backup dump archives symbolic links as links, otherwise the restore will corrupt your tablespaces).

You can, however, omit from the backup dump the files within the cluster's `pg_xlog/` subdirectory. This slight adjustment is worthwhile because it reduces the risk of mistakes when restoring. This is easy to arrange if `pg_xlog/` is a symbolic link pointing to someplace outside the cluster directory, which is a common setup anyway for performance reasons. You might also want to exclude `postmaster.pid` and `postmaster.opts`, which record information about the running postmaster, not about the postmaster which will eventually use this backup. (These files can confuse pg_ctl.)

It is often a good idea to also omit from the backup dump the files within the cluster's `pg_replslot/` directory, so that replication slots that exist on the master do not become part of the backup. Otherwise, the subsequent use of the backup to create a standby may result in indefinite retention of WAL files on the standby, and possibly bloat on the master if hot standby feedback is enabled, because the clients that are using those replication slots will still be connecting to and updating the slots on the master, not the standby. Even if the backup is only intended for use in creating a new master, copying the replication slots isn't expected to be particularly useful, since the contents of those slots will likely be badly out of date by the time the new master comes on line.

It's also worth noting that the `pg_start_backup` function makes a file named `backup_label` in the database cluster directory, which is removed by `pg_stop_backup`. This file will of course be archived as a part of your backup dump file. The backup label file includes the label string you gave to `pg_start_backup`, as well as the time at which `pg_start_backup` was run, and the name of the starting WAL file. In case of confusion it is therefore possible to look inside a backup dump file and determine exactly which backup session the dump file came from. However, this file is not merely for your information; its presence and contents are critical to the proper operation of the system's recovery process.

It is also possible to make a backup dump while the server is stopped. In this case, you obviously cannot use `pg_start_backup` or `pg_stop_backup`, and you will therefore be left to your own devices to keep track of which backup dump is which and how far back the associated WAL files go. It is generally better to follow the continuous archiving procedure above.

24.3.4. Recovering Using a Continuous Archive Backup

Okay, the worst has happened and you need to recover from your backup. Here is the procedure:

1. Stop the server, if it's running.
2. If you have the space to do so, copy the whole cluster data directory and any tablespaces to a temporary location in case you need them later. Note that this precaution will require that you

have enough free space on your system to hold two copies of your existing database. If you do not have enough space, you should at least save the contents of the cluster's pg_xlog subdirectory, as it might contain logs which were not archived before the system went down.

3. Remove all existing files and subdirectories under the cluster data directory and under the root directories of any tablespaces you are using.
4. Restore the database files from your file system backup. Be sure that they are restored with the right ownership (the database system user, not root!) and with the right permissions. If you are using tablespaces, you should verify that the symbolic links in pg_tblspc/ were correctly restored.
5. Remove any files present in pg_xlog/; these came from the file system backup and are therefore probably obsolete rather than current. If you didn't archive pg_xlog/ at all, then recreate it with proper permissions, being careful to ensure that you re-establish it as a symbolic link if you had it set up that way before.
6. If you have unarchived WAL segment files that you saved in step 2, copy them into pg_xlog/. (It is best to copy them, not move them, so you still have the unmodified files if a problem occurs and you have to start over.)
7. Create a recovery command file recovery.conf in the cluster data directory (see Chapter 26). You might also want to temporarily modify pg_hba.conf to prevent ordinary users from connecting until you are sure the recovery was successful.
8. Start the server. The server will go into recovery mode and proceed to read through the archived WAL files it needs. Should the recovery be terminated because of an external error, the server can simply be restarted and it will continue recovery. Upon completion of the recovery process, the server will rename recovery.conf to recovery.done (to prevent accidentally re-entering recovery mode later) and then commence normal database operations.
9. Inspect the contents of the database to ensure you have recovered to the desired state. If not, return to step 1. If all is well, allow your users to connect by restoring pg_hba.conf to normal.

The key part of all this is to set up a recovery configuration file that describes how you want to recover and how far the recovery should run. You can use recovery.conf.sample (normally located in the installation's share/ directory) as a prototype. The one thing that you absolutely must specify in recovery.conf is the restore_command, which tells PostgreSQL how to retrieve archived WAL file segments. Like the archive_command, this is a shell command string. It can contain %f, which is replaced by the name of the desired log file, and %p, which is replaced by the path name to copy the log file to. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Write %% if you need to embed an actual % character in the command. The simplest useful command is something like:

```
restore_command = 'cp /mnt/server/archivedir/%f %p'
```

which will copy previously archived WAL segments from the directory /mnt/server/archivedir. Of course, you can use something much more complicated, perhaps even a shell script that requests the operator to mount an appropriate tape.

It is important that the command return nonzero exit status on failure. The command *will* be called requesting files that are not present in the archive; it must return nonzero when so asked. This is not an error condition. An exception is that if the command was terminated by a signal (other than SIGTERM, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

Not all of the requested files will be WAL segment files; you should also expect requests for files with a suffix of `.backup` or `.history`. Also be aware that the base name of the `%p` path will be different from `%f`; do not expect them to be interchangeable.

WAL segments that cannot be found in the archive will be sought in `pg_xlog/`; this allows use of recent un-archived segments. However, segments that are available from the archive will be used in preference to files in `pg_xlog/`.

Normally, recovery will proceed through all available WAL segments, thereby restoring the database to the current point in time (or as close as possible given the available WAL segments). Therefore, a normal recovery will end with a "file not found" message, the exact text of the error message depending upon your choice of `restore_command`. You may also see an error message at the start of recovery for a file named something like `00000001.history`. This is also normal and does not indicate a problem in simple recovery situations; see Section 24.3.5 for discussion.

If you want to recover to some previous point in time (say, right before the junior DBA dropped your main transaction table), just specify the required stopping point in `recovery.conf`. You can specify the stop point, known as the "recovery target", either by date/time, named restore point or by completion of a specific transaction ID. As of this writing only the date/time and named restore point options are very usable, since there are no tools to help you identify with any accuracy which transaction ID to use.

> **Note:** The stop point must be after the ending time of the base backup, i.e., the end time of `pg_stop_backup`. You cannot use a base backup to recover to a time when that backup was in progress. (To recover to such a time, you must go back to your previous base backup and roll forward from there.)

If recovery finds corrupted WAL data, recovery will halt at that point and the server will not start. In such a case the recovery process could be re-run from the beginning, specifying a "recovery target" before the point of corruption so that recovery can complete normally. If recovery fails for an external reason, such as a system crash or if the WAL archive has become inaccessible, then the recovery can simply be restarted and it will restart almost from where it failed. Recovery restart works much like checkpointing in normal operation: the server periodically forces all its state to disk, and then updates the `pg_control` file to indicate that the already-processed WAL data need not be scanned again.

24.3.5. Timelines

The ability to restore the database to a previous point in time creates some complexities that are akin to science-fiction stories about time travel and parallel universes. For example, in the original history of the database, suppose you dropped a critical table at 5:15PM on Tuesday evening, but didn't realize your mistake until Wednesday noon. Unfazed, you get out your backup, restore to the point-in-time 5:14PM Tuesday evening, and are up and running. In *this* history of the database universe, you never dropped the table. But suppose you later realize this wasn't such a great idea, and would like to return to sometime Wednesday morning in the original history. You won't be able to if, while your database was up-and-running, it overwrote some of the WAL segment files that led up to the time you now wish you could get back to. Thus, to avoid this, you need to distinguish the series of WAL records generated after you've done a point-in-time recovery from those that were generated in the original database history.

To deal with this problem, PostgreSQL has a notion of *timelines*. Whenever an archive recovery completes, a new timeline is created to identify the series of WAL records generated after that recovery. The timeline ID number is part of WAL segment file names so a new timeline does not overwrite the

WAL data generated by previous timelines. It is in fact possible to archive many different timelines. While that might seem like a useless feature, it's often a lifesaver. Consider the situation where you aren't quite sure what point-in-time to recover to, and so have to do several point-in-time recoveries by trial and error until you find the best place to branch off from the old history. Without timelines this process would soon generate an unmanageable mess. With timelines, you can recover to *any* prior state, including states in timeline branches that you abandoned earlier.

Every time a new timeline is created, PostgreSQL creates a "timeline history" file that shows which timeline it branched off from and when. These history files are necessary to allow the system to pick the right WAL segment files when recovering from an archive that contains multiple timelines. Therefore, they are archived into the WAL archive area just like WAL segment files. The history files are just small text files, so it's cheap and appropriate to keep them around indefinitely (unlike the segment files which are large). You can, if you like, add comments to a history file to record your own notes about how and why this particular timeline was created. Such comments will be especially valuable when you have a thicket of different timelines as a result of experimentation.

The default behavior of recovery is to recover along the same timeline that was current when the base backup was taken. If you wish to recover into some child timeline (that is, you want to return to some state that was itself generated after a recovery attempt), you need to specify the target timeline ID in `recovery.conf`. You cannot recover into timelines that branched off earlier than the base backup.

24.3.6. Tips and Examples

Some tips for configuring continuous archiving are given here.

24.3.6.1. Standalone Hot Backups

It is possible to use PostgreSQL's backup facilities to produce standalone hot backups. These are backups that cannot be used for point-in-time recovery, yet are typically much faster to backup and restore than pg_dump dumps. (They are also much larger than pg_dump dumps, so in some cases the speed advantage might be negated.)

As with base backups, the easiest way to produce a standalone hot backup is to use the pg_basebackup tool. If you include the `-X` parameter when calling it, all the transaction log required to use the backup will be included in the backup automatically, and no special action is required to restore the backup.

If more flexibility in copying the backup files is needed, a lower level process can be used for standalone hot backups as well. To prepare for low level standalone hot backups, set `wal_level` to `archive` or higher, `archive_mode` to `on`, and set up an `archive_command` that performs archiving only when a *switch file* exists. For example:

```
archive_command = 'test ! -f /var/lib/pgsql/backup_in_progress || (test ! -f /var/lib/pg
```

This command will perform archiving when `/var/lib/pgsql/backup_in_progress` exists, and otherwise silently return zero exit status (allowing PostgreSQL to recycle the unwanted WAL file).

With this preparation, a backup can be taken using a script like the following:

```
touch /var/lib/pgsql/backup_in_progress
psql -c "select pg_start_backup('hot_backup');"
tar -cf /var/lib/pgsql/backup.tar /var/lib/pgsql/data/
psql -c "select pg_stop_backup();"
rm /var/lib/pgsql/backup_in_progress
tar -rf /var/lib/pgsql/backup.tar /var/lib/pgsql/archive/
```

The switch file /var/lib/pgsql/backup_in_progress is created first, enabling archiving of completed WAL files to occur. After the backup the switch file is removed. Archived WAL files are then added to the backup so that both base backup and all required WAL files are part of the same tar file. Please remember to add error handling to your backup scripts.

24.3.6.2. Compressed Archive Logs

If archive storage size is a concern, you can use gzip to compress the archive files:

```
archive_command = 'gzip < %p > /var/lib/pgsql/archive/%f'
```

You will then need to use gunzip during recovery:

```
restore_command = 'gunzip < /mnt/server/archivedir/%f > %p'
```

24.3.6.3. `archive_command` Scripts

Many people choose to use scripts to define their archive_command, so that their postgresql.conf entry looks very simple:

```
archive_command = 'local_backup_script.sh "%p" "%f"'
```

Using a separate script file is advisable any time you want to use more than a single command in the archiving process. This allows all complexity to be managed within the script, which can be written in a popular scripting language such as bash or perl.

Examples of requirements that might be solved within a script include:

- Copying data to secure off-site data storage
- Batching WAL files so that they are transferred every three hours, rather than one at a time
- Interfacing with other backup and recovery software
- Interfacing with monitoring software to report errors

> **Tip:** When using an archive_command script, it's desirable to enable logging_collector. Any messages written to stderr from the script will then appear in the database server log, allowing complex configurations to be diagnosed easily if they fail.

24.3.7. Caveats

At this writing, there are several limitations of the continuous archiving technique. These will probably be fixed in future releases:

- Operations on hash indexes are not presently WAL-logged, so replay will not update these indexes. This will mean that any new inserts will be ignored by the index, updated rows will apparently

disappear and deleted rows will still retain pointers. In other words, if you modify a table with a hash index on it then you will get incorrect query results on a standby server. When recovery completes it is recommended that you manually REINDEX each such index after completing a recovery operation.

- If a CREATE DATABASE command is executed while a base backup is being taken, and then the template database that the `CREATE DATABASE` copied is modified while the base backup is still in progress, it is possible that recovery will cause those modifications to be propagated into the created database as well. This is of course undesirable. To avoid this risk, it is best not to modify any template databases while taking a base backup.
- CREATE TABLESPACE commands are WAL-logged with the literal absolute path, and will therefore be replayed as tablespace creations with the same absolute path. This might be undesirable if the log is being replayed on a different machine. It can be dangerous even if the log is being replayed on the same machine, but into a new data directory: the replay will still overwrite the contents of the original tablespace. To avoid potential gotchas of this sort, the best practice is to take a new base backup after creating or dropping tablespaces.

It should also be noted that the default WAL format is fairly bulky since it includes many disk page snapshots. These page snapshots are designed to support crash recovery, since we might need to fix partially-written disk pages. Depending on your system hardware and software, the risk of partial writes might be small enough to ignore, in which case you can significantly reduce the total volume of archived logs by turning off page snapshots using the full_page_writes parameter. (Read the notes and warnings in Chapter 29 before you do so.) Turning off page snapshots does not prevent use of the logs for PITR operations. An area for future development is to compress archived WAL data by removing unnecessary page copies even when `full_page_writes` is on. In the meantime, administrators might wish to reduce the number of page snapshots included in WAL by increasing the checkpoint interval parameters as much as feasible.

Chapter 25. High Availability, Load Balancing, and Replication

Database servers can work together to allow a second server to take over quickly if the primary server fails (high availability), or to allow several computers to serve the same data (load balancing). Ideally, database servers could work together seamlessly. Web servers serving static web pages can be combined quite easily by merely load-balancing web requests to multiple machines. In fact, read-only database servers can be combined relatively easily too. Unfortunately, most database servers have a read/write mix of requests, and read/write servers are much harder to combine. This is because though read-only data needs to be placed on each server only once, a write to any server has to be propagated to all servers so that future read requests to those servers return consistent results.

This synchronization problem is the fundamental difficulty for servers working together. Because there is no single solution that eliminates the impact of the sync problem for all use cases, there are multiple solutions. Each solution addresses this problem in a different way, and minimizes its impact for a specific workload.

Some solutions deal with synchronization by allowing only one server to modify the data. Servers that can modify data are called read/write, *master* or *primary* servers. Servers that track changes in the master are called *standby* or *slave* servers. A standby server that cannot be connected to until it is promoted to a master server is called a *warm standby* server, and one that can accept connections and serves read-only queries is called a *hot standby* server.

Some solutions are synchronous, meaning that a data-modifying transaction is not considered committed until all servers have committed the transaction. This guarantees that a failover will not lose any data and that all load-balanced servers will return consistent results no matter which server is queried. In contrast, asynchronous solutions allow some delay between the time of a commit and its propagation to the other servers, opening the possibility that some transactions might be lost in the switch to a backup server, and that load balanced servers might return slightly stale results. Asynchronous communication is used when synchronous would be too slow.

Solutions can also be categorized by their granularity. Some solutions can deal only with an entire database server, while others allow control at the per-table or per-database level.

Performance must be considered in any choice. There is usually a trade-off between functionality and performance. For example, a fully synchronous solution over a slow network might cut performance by more than half, while an asynchronous one might have a minimal performance impact.

The remainder of this section outlines various failover, replication, and load balancing solutions. A glossary[1] is also available.

25.1. Comparison of Different Solutions

Shared Disk Failover

Shared disk failover avoids synchronization overhead by having only one copy of the database. It uses a single disk array that is shared by multiple servers. If the main database server fails, the standby server is able to mount and start the database as though it were recovering from a database crash. This allows rapid failover with no data loss.

Shared hardware functionality is common in network storage devices. Using a network file system is also possible, though care must be taken that the file system has full POSIX behavior (see

1. http://www.postgres-r.org/documentation/terms

Section 17.2.1). One significant limitation of this method is that if the shared disk array fails or becomes corrupt, the primary and standby servers are both nonfunctional. Another issue is that the standby server should never access the shared storage while the primary server is running.

File System (Block-Device) Replication

A modified version of shared hardware functionality is file system replication, where all changes to a file system are mirrored to a file system residing on another computer. The only restriction is that the mirroring must be done in a way that ensures the standby server has a consistent copy of the file system — specifically, writes to the standby must be done in the same order as those on the master. DRBD is a popular file system replication solution for Linux.

Transaction Log Shipping

Warm and hot standby servers can be kept current by reading a stream of write-ahead log (WAL) records. If the main server fails, the standby contains almost all of the data of the main server, and can be quickly made the new master database server. This can be synchronous or asynchronous and can only be done for the entire database server.

A standby server can be implemented using file-based log shipping (Section 25.2) or streaming replication (see Section 25.2.5), or a combination of both. For information on hot standby, see Section 25.5.

Trigger-Based Master-Standby Replication

A master-standby replication setup sends all data modification queries to the master server. The master server asynchronously sends data changes to the standby server. The standby can answer read-only queries while the master server is running. The standby server is ideal for data warehouse queries.

Slony-I is an example of this type of replication, with per-table granularity, and support for multiple standby servers. Because it updates the standby server asynchronously (in batches), there is possible data loss during fail over.

Statement-Based Replication Middleware

With statement-based replication middleware, a program intercepts every SQL query and sends it to one or all servers. Each server operates independently. Read-write queries must be sent to all servers, so that every server receives any changes. But read-only queries can be sent to just one server, allowing the read workload to be distributed among them.

If queries are simply broadcast unmodified, functions like `random()`, `CURRENT_TIMESTAMP`, and sequences can have different values on different servers. This is because each server operates independently, and because SQL queries are broadcast (and not actual modified rows). If this is unacceptable, either the middleware or the application must query such values from a single server and then use those values in write queries. Another option is to use this replication option with a traditional master-standby setup, i.e. data modification queries are sent only to the master and are propagated to the standby servers via master-standby replication, not by the replication middleware. Care must also be taken that all transactions either commit or abort on all servers, perhaps using two-phase commit (PREPARE TRANSACTION and COMMIT PREPARED. Pgpool-II and Continuent Tungsten are examples of this type of replication.

Asynchronous Multimaster Replication

For servers that are not regularly connected, like laptops or remote servers, keeping data consistent among servers is a challenge. Using asynchronous multimaster replication, each server works independently, and periodically communicates with the other servers to identify conflicting transactions. The conflicts can be resolved by users or conflict resolution rules. Bucardo is an example of this type of replication.

Synchronous Multimaster Replication

In synchronous multimaster replication, each server can accept write requests, and modified data is transmitted from the original server to every other server before each transaction commits. Heavy write activity can cause excessive locking, leading to poor performance. In fact, write performance is often worse than that of a single server. Read requests can be sent to any server. Some implementations use shared disk to reduce the communication overhead. Synchronous multimaster replication is best for mostly read workloads, though its big advantage is that any server can accept write requests — there is no need to partition workloads between master and standby servers, and because the data changes are sent from one server to another, there is no problem with non-deterministic functions like `random()`.

PostgreSQL does not offer this type of replication, though PostgreSQL two-phase commit (PREPARE TRANSACTION and COMMIT PREPARED) can be used to implement this in application code or middleware.

Commercial Solutions

Because PostgreSQL is open source and easily extended, a number of companies have taken PostgreSQL and created commercial closed-source solutions with unique failover, replication, and load balancing capabilities.

Table 25-1 summarizes the capabilities of the various solutions listed above.

Table 25-1. High Availability, Load Balancing, and Replication Feature Matrix

Feature	Shared Disk Failover	File System Replication	Transaction Log Shipping	Trigger-Based Master-Standby Replication	Statement-Based Replication Middleware	Asynchronous Multimaster Replication	Synchronous Multimaster Replication
Most Common Implementation	NAS	DRBD	Streaming Repl.	Slony	pgpool-II	Bucardo	
Communication Method	shared disk	disk blocks	WAL	table rows	SQL	table rows	table rows and row locks
No special hardware required		•	•	•	•	•	•
Allows multiple master servers					•	•	•
No master server overhead	•		•		•		

Feature	Shared Disk Failover	File System Replication	Transaction Log Shipping	Trigger-Based Master-Standby Replication	Statement-Based Replication Middleware	Asynchronous Multi-master Replication	Synchronous Multi-master Replication
No waiting for multiple servers	•		with sync off	•		•	
Master failure will never lose data	•	•	with sync on		•		•
Standby accept read-only queries			with hot	•	•	•	•
Per-table granularity				•		•	•
No conflict resolution necessary	•	•	•	•			•

There are a few solutions that do not fit into the above categories:

Data Partitioning

Data partitioning splits tables into data sets. Each set can be modified by only one server. For example, data can be partitioned by offices, e.g., London and Paris, with a server in each office. If queries combining London and Paris data are necessary, an application can query both servers, or master/standby replication can be used to keep a read-only copy of the other office's data on each server.

Multiple-Server Parallel Query Execution

Many of the above solutions allow multiple servers to handle multiple queries, but none allow a single query to use multiple servers to complete faster. This solution allows multiple servers to work concurrently on a single query. It is usually accomplished by splitting the data among servers and having each server execute its part of the query and return results to a central server where they are combined and returned to the user. Pgpool-II has this capability. Also, this can be implemented using the PL/Proxy tool set.

25.2. Log-Shipping Standby Servers

Continuous archiving can be used to create a *high availability* (HA) cluster configuration with one or more *standby servers* ready to take over operations if the primary server fails. This capability is widely referred to as *warm standby* or *log shipping*.

The primary and standby server work together to provide this capability, though the servers are only loosely coupled. The primary server operates in continuous archiving mode, while each standby server operates in continuous recovery mode, reading the WAL files from the primary. No changes to the database tables are required to enable this capability, so it offers low administration overhead compared to some other replication solutions. This configuration also has relatively low performance impact on the primary server.

Directly moving WAL records from one database server to another is typically described as log shipping. PostgreSQL implements file-based log shipping by transferring WAL records one file (WAL segment) at a time. WAL files (16MB) can be shipped easily and cheaply over any distance, whether it be to an adjacent system, another system at the same site, or another system on the far side of the globe. The bandwidth required for this technique varies according to the transaction rate of the primary server. Record-based log shipping is more granular and streams WAL changes incrementally over a network connection (see Section 25.2.5).

It should be noted that log shipping is asynchronous, i.e., the WAL records are shipped after transaction commit. As a result, there is a window for data loss should the primary server suffer a catastrophic failure; transactions not yet shipped will be lost. The size of the data loss window in file-based log shipping can be limited by use of the `archive_timeout` parameter, which can be set as low as a few seconds. However such a low setting will substantially increase the bandwidth required for file shipping. Streaming replication (see Section 25.2.5) allows a much smaller window of data loss.

Recovery performance is sufficiently good that the standby will typically be only moments away from full availability once it has been activated. As a result, this is called a warm standby configuration which offers high availability. Restoring a server from an archived base backup and rollforward will take considerably longer, so that technique only offers a solution for disaster recovery, not high availability. A standby server can also be used for read-only queries, in which case it is called a Hot Standby server. See Section 25.5 for more information.

25.2.1. Planning

It is usually wise to create the primary and standby servers so that they are as similar as possible, at least from the perspective of the database server. In particular, the path names associated with tablespaces will be passed across unmodified, so both primary and standby servers must have the same mount paths for tablespaces if that feature is used. Keep in mind that if CREATE TABLESPACE is executed on the primary, any new mount point needed for it must be created on the primary and all standby servers before the command is executed. Hardware need not be exactly the same, but experience shows that maintaining two identical systems is easier than maintaining two dissimilar ones over the lifetime of the application and system. In any case the hardware architecture must be the same — shipping from, say, a 32-bit to a 64-bit system will not work.

In general, log shipping between servers running different major PostgreSQL release levels is not possible. It is the policy of the PostgreSQL Global Development Group not to make changes to disk formats during minor release upgrades, so it is likely that running different minor release levels on primary and standby servers will work successfully. However, no formal support for that is offered and you are advised to keep primary and standby servers at the same release level as much as possible. When updating to a new minor release, the safest policy is to update the standby servers first — a new minor release is more likely to be able to read WAL files from a previous minor release than vice versa.

25.2.2. Standby Server Operation

In standby mode, the server continuously applies WAL received from the master server. The standby server can read WAL from a WAL archive (see restore_command) or directly from the master over a TCP connection (streaming replication). The standby server will also attempt to restore any WAL found in the standby cluster's `pg_xlog` directory. That typically happens after a server restart, when the standby replays again WAL that was streamed from the master before the restart, but you can also manually copy files to `pg_xlog` at any time to have them replayed.

At startup, the standby begins by restoring all WAL available in the archive location, calling `restore_command`. Once it reaches the end of WAL available there and `restore_command` fails, it tries to restore any WAL available in the `pg_xlog` directory. If that fails, and streaming replication has been configured, the standby tries to connect to the primary server and start streaming WAL from the last valid record found in archive or `pg_xlog`. If that fails or streaming replication is not configured, or if the connection is later disconnected, the standby goes back to step 1 and tries to restore the file from the archive again. This loop of retries from the archive, `pg_xlog`, and via streaming replication goes on until the server is stopped or failover is triggered by a trigger file.

Standby mode is exited and the server switches to normal operation when `pg_ctl promote` is run or a trigger file is found (`trigger_file`). Before failover, any WAL immediately available in the archive or in `pg_xlog` will be restored, but no attempt is made to connect to the master.

25.2.3. Preparing the Master for Standby Servers

Set up continuous archiving on the primary to an archive directory accessible from the standby, as described in Section 24.3. The archive location should be accessible from the standby even when the master is down, i.e. it should reside on the standby server itself or another trusted server, not on the master server.

If you want to use streaming replication, set up authentication on the primary server to allow replication connections from the standby server(s); that is, create a role and provide a suitable entry or entries in `pg_hba.conf` with the database field set to `replication`. Also ensure `max_wal_senders` is set to a sufficiently large value in the configuration file of the primary server. If replication slots will be used, ensure that `max_replication_slots` is set sufficiently high as well.

Take a base backup as described in Section 24.3.2 to bootstrap the standby server.

25.2.4. Setting Up a Standby Server

To set up the standby server, restore the base backup taken from primary server (see Section 24.3.4). Create a recovery command file `recovery.conf` in the standby's cluster data directory, and turn on `standby_mode`. Set `restore_command` to a simple command to copy files from the WAL archive. If you plan to have multiple standby servers for high availability purposes, set `recovery_target_timeline` to `latest`, to make the standby server follow the timeline change that occurs at failover to another standby.

> **Note:** Do not use pg_standby or similar tools with the built-in standby mode described here. `restore_command` should return immediately if the file does not exist; the server will retry the command again if necessary. See Section 25.4 for using tools like pg_standby.

If you want to use streaming replication, fill in primary_conninfo with a libpq connection string, including the host name (or IP address) and any additional details needed to connect to the primary server. If the primary needs a password for authentication, the password needs to be specified in primary_conninfo as well.

If you're setting up the standby server for high availability purposes, set up WAL archiving, connections and authentication like the primary server, because the standby server will work as a primary server after failover.

If you're using a WAL archive, its size can be minimized using the archive_cleanup_command parameter to remove files that are no longer required by the standby server. The pg_archivecleanup utility is designed specifically to be used with archive_cleanup_command in typical single-standby configurations, see pg_archivecleanup. Note however, that if you're using the archive for backup purposes, you need to retain files needed to recover from at least the latest base backup, even if they're no longer needed by the standby.

A simple example of a recovery.conf is:

```
standby_mode = 'on'
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo password=foopass'
restore_command = 'cp /path/to/archive/%f %p'
archive_cleanup_command = 'pg_archivecleanup /path/to/archive %r'
```

You can have any number of standby servers, but if you use streaming replication, make sure you set max_wal_senders high enough in the primary to allow them to be connected simultaneously.

25.2.5. Streaming Replication

Streaming replication allows a standby server to stay more up-to-date than is possible with file-based log shipping. The standby connects to the primary, which streams WAL records to the standby as they're generated, without waiting for the WAL file to be filled.

Streaming replication is asynchronous by default (see Section 25.2.8), in which case there is a small delay between committing a transaction in the primary and the changes becoming visible in the standby. This delay is however much smaller than with file-based log shipping, typically under one second assuming the standby is powerful enough to keep up with the load. With streaming replication, archive_timeout is not required to reduce the data loss window.

If you use streaming replication without file-based continuous archiving, the server might recycle old WAL segments before the standby has received them. If this occurs, the standby will need to be reinitialized from a new base backup. You can avoid this by setting wal_keep_segments to a value large enough to ensure that WAL segments are not recycled too early, or by configuring a replication slot for the standby. If you set up a WAL archive that's accessible from the standby, these solutions are not required, since the standby can always use the archive to catch up provided it retains enough segments.

To use streaming replication, set up a file-based log-shipping standby server as described in Section 25.2. The step that turns a file-based log-shipping standby into streaming replication standby is setting primary_conninfo setting in the recovery.conf file to point to the primary server. Set listen_addresses and authentication options (see pg_hba.conf) on the primary so that the standby server can connect to the replication pseudo-database on the primary server (see Section 25.2.5.1).

On systems that support the keepalive socket option, setting tcp_keepalives_idle, tcp_keepalives_interval and tcp_keepalives_count helps the primary promptly notice a broken connection.

Set the maximum number of concurrent connections from the standby servers (see max_wal_senders for details).

When the standby is started and `primary_conninfo` is set correctly, the standby will connect to the primary after replaying all WAL files available in the archive. If the connection is established successfully, you will see a walreceiver process in the standby, and a corresponding walsender process in the primary.

25.2.5.1. Authentication

It is very important that the access privileges for replication be set up so that only trusted users can read the WAL stream, because it is easy to extract privileged information from it. Standby servers must authenticate to the primary as a superuser or an account that has the `REPLICATION` privilege. It is recommended to create a dedicated user account with `REPLICATION` and `LOGIN` privileges for replication. While `REPLICATION` privilege gives very high permissions, it does not allow the user to modify any data on the primary system, which the `SUPERUSER` privilege does.

Client authentication for replication is controlled by a `pg_hba.conf` record specifying `replication` in the *`database`* field. For example, if the standby is running on host IP `192.168.1.100` and the account name for replication is `foo`, the administrator can add the following line to the `pg_hba.conf` file on the primary:

```
# Allow the user "foo" from host 192.168.1.100 to connect to the primary
# as a replication standby if the user's password is correctly supplied.
#
# TYPE  DATABASE        USER            ADDRESS                 METHOD
host    replication     foo             192.168.1.100/32        md5
```

The host name and port number of the primary, connection user name, and password are specified in the `recovery.conf` file. The password can also be set in the `~/.pgpass` file on the standby (specify `replication` in the *`database`* field). For example, if the primary is running on host IP `192.168.1.50`, port `5432`, the account name for replication is `foo`, and the password is `foopass`, the administrator can add the following line to the `recovery.conf` file on the standby:

```
# The standby connects to the primary that is running on host 192.168.1.50
# and port 5432 as the user "foo" whose password is "foopass".
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo password=foopass'
```

25.2.5.2. Monitoring

An important health indicator of streaming replication is the amount of WAL records generated in the primary, but not yet applied in the standby. You can calculate this lag by comparing the current WAL write location on the primary with the last WAL location received by the standby. They can be retrieved using `pg_current_xlog_location` on the primary and the `pg_last_xlog_receive_location` on the standby, respectively (see Table 9-65 and Table 9-66 for details). The last WAL receive location in the standby is also displayed in the process status of the WAL receiver process, displayed using the `ps` command (see Section 27.1 for details).

You can retrieve a list of WAL sender processes via the pg_stat_replication view. Large differences between pg_current_xlog_location and sent_location field might indicate that the master server is under heavy load, while differences between sent_location and pg_last_xlog_receive_location on the standby might indicate network delay, or that the standby is under heavy load.

25.2.6. Replication Slots

Replication slots provide an automated way to ensure that the master does not remove WAL segments until they have been received by all standbys, and that the master does not remove rows which could cause a recovery conflict even when the standby is disconnected.

In lieu of using replication slots, it is possible to prevent the removal of old WAL segments using wal_keep_segments, or by storing the segments in an archive using archive_command. However, these methods often result in retaining more WAL segments than required, whereas replication slots retain only the number of segments known to be needed. An advantage of these methods is that they bound the space requirement for pg_xlog; there is currently no way to do this using replication slots.

Similarly, hot_standby_feedback and vacuum_defer_cleanup_age provide protection against relevant rows being removed by vacuum, but the former provides no protection during any time period when the standby is not connected, and the latter often needs to be set to a high value to provide adequate protection. Replication slots overcome these disadvantages.

25.2.6.1. Querying and manipulating replication slots

Each replication slot has a name, which can contain lower-case letters, numbers, and the underscore character.

Existing replication slots and their state can be seen in the pg_replication_slots view.

Slots can be created and dropped either via the streaming replication protocol (see Section 49.3) or via SQL functions (see Section 9.26.6).

25.2.6.2. Configuration Example

You can create a replication slot like this:

```
postgres=# SELECT * FROM pg_create_physical_replication_slot('node_a_slot');
  slot_name  | xlog_position
-------------+---------------
 node_a_slot |

postgres=# SELECT * FROM pg_replication_slots;
  slot_name  | slot_type | datoid | database | active | xmin | restart_lsn
-------------+-----------+--------+----------+--------+------+-------------
 node_a_slot | physical  |        |          | f      |      |
(1 row)
```

To configure the standby to use this slot, primary_slot_name should be configured in the standby's recovery.conf. Here is a simple example:

```
standby_mode = 'on'
primary_conninfo = 'host=192.168.1.50 port=5432 user=foo password=foopass'
primary_slot_name = 'node_a_slot'
```

25.2.7. Cascading Replication

The cascading replication feature allows a standby server to accept replication connections and stream WAL records to other standbys, acting as a relay. This can be used to reduce the number of direct connections to the master and also to minimize inter-site bandwidth overheads.

A standby acting as both a receiver and a sender is known as a cascading standby. Standbys that are more directly connected to the master are known as upstream servers, while those standby servers further away are downstream servers. Cascading replication does not place limits on the number or arrangement of downstream servers, though each standby connects to only one upstream server which eventually links to a single master/primary server.

A cascading standby sends not only WAL records received from the master but also those restored from the archive. So even if the replication connection in some upstream connection is terminated, streaming replication continues downstream for as long as new WAL records are available.

Cascading replication is currently asynchronous. Synchronous replication (see Section 25.2.8) settings have no effect on cascading replication at present.

Hot Standby feedback propagates upstream, whatever the cascaded arrangement.

If an upstream standby server is promoted to become new master, downstream servers will continue to stream from the new master if `recovery_target_timeline` is set to `'latest'`.

To use cascading replication, set up the cascading standby so that it can accept replication connections (that is, set max_wal_senders and hot_standby, and configure host-based authentication). You will also need to set `primary_conninfo` in the downstream standby to point to the cascading standby.

25.2.8. Synchronous Replication

PostgreSQL streaming replication is asynchronous by default. If the primary server crashes then some transactions that were committed may not have been replicated to the standby server, causing data loss. The amount of data loss is proportional to the replication delay at the time of failover.

Synchronous replication offers the ability to confirm that all changes made by a transaction have been transferred to one synchronous standby server. This extends the standard level of durability offered by a transaction commit. This level of protection is referred to as 2-safe replication in computer science theory.

When requesting synchronous replication, each commit of a write transaction will wait until confirmation is received that the commit has been written to the transaction log on disk of both the primary and standby server. The only possibility that data can be lost is if both the primary and the standby suffer crashes at the same time. This can provide a much higher level of durability, though only if the sysadmin is cautious about the placement and management of the two servers. Waiting for confirmation increases the user's confidence that the changes will not be lost in the event of server crashes but it also necessarily increases the response time for the requesting transaction. The minimum wait time is the roundtrip time between primary to standby.

Read only transactions and transaction rollbacks need not wait for replies from standby servers. Subtransaction commits do not wait for responses from standby servers, only top-level commits. Long running actions such as data loading or index building do not wait until the very final commit message. All two-phase commit actions require commit waits, including both prepare and commit.

25.2.8.1. Basic Configuration

Once streaming replication has been configured, configuring synchronous replication requires only one additional configuration step: synchronous_standby_names must be set to a non-empty value. `synchronous_commit` must also be set to `on`, but since this is the default value, typically no change is required. (See Section 18.5.1 and Section 18.6.2.) This configuration will cause each commit to wait for confirmation that the standby has written the commit record to durable storage. `synchronous_commit` can be set by individual users, so it can be configured in the configuration file, for particular users or databases, or dynamically by applications, in order to control the durability guarantee on a per-transaction basis.

After a commit record has been written to disk on the primary, the WAL record is then sent to the standby. The standby sends reply messages each time a new batch of WAL data is written to disk, unless `wal_receiver_status_interval` is set to zero on the standby. If the standby is the first matching standby, as specified in `synchronous_standby_names` on the primary, the reply messages from that standby will be used to wake users waiting for confirmation that the commit record has been received. These parameters allow the administrator to specify which standby servers should be synchronous standbys. Note that the configuration of synchronous replication is mainly on the master. Named standbys must be directly connected to the master; the master knows nothing about downstream standby servers using cascaded replication.

Setting `synchronous_commit` to `remote_write` will cause each commit to wait for confirmation that the standby has received the commit record and written it out to its own operating system, but not for the data to be flushed to disk on the standby. This setting provides a weaker guarantee of durability than `on` does: the standby could lose the data in the event of an operating system crash, though not a PostgreSQL crash. However, it's a useful setting in practice because it can decrease the response time for the transaction. Data loss could only occur if both the primary and the standby crash and the database of the primary gets corrupted at the same time.

Users will stop waiting if a fast shutdown is requested. However, as when using asynchronous replication, the server will not fully shutdown until all outstanding WAL records are transferred to the currently connected standby servers.

25.2.8.2. Planning for Performance

Synchronous replication usually requires carefully planned and placed standby servers to ensure applications perform acceptably. Waiting doesn't utilize system resources, but transaction locks continue to be held until the transfer is confirmed. As a result, incautious use of synchronous replication will reduce performance for database applications because of increased response times and higher contention.

PostgreSQL allows the application developer to specify the durability level required via replication. This can be specified for the system overall, though it can also be specified for specific users or connections, or even individual transactions.

For example, an application workload might consist of: 10% of changes are important customer details, while 90% of changes are less important data that the business can more easily survive if it is lost, such as chat messages between users.

With synchronous replication options specified at the application level (on the primary) we can offer synchronous replication for the most important changes, without slowing down the bulk of the total workload. Application level options are an important and practical tool for allowing the benefits of synchronous replication for high performance applications.

You should consider that the network bandwidth must be higher than the rate of generation of WAL data.

25.2.8.3. Planning for High Availability

Commits made when `synchronous_commit` is set to `on` or `remote_write` will wait until the synchronous standby responds. The response may never occur if the last, or only, standby should crash.

The best solution for avoiding data loss is to ensure you don't lose your last remaining synchronous standby. This can be achieved by naming multiple potential synchronous standbys using `synchronous_standby_names`. The first named standby will be used as the synchronous standby. Standbys listed after this will take over the role of synchronous standby if the first one should fail.

When a standby first attaches to the primary, it will not yet be properly synchronized. This is described as `catchup` mode. Once the lag between standby and primary reaches zero for the first time we move to real-time `streaming` state. The catch-up duration may be long immediately after the standby has been created. If the standby is shut down, then the catch-up period will increase according to the length of time the standby has been down. The standby is only able to become a synchronous standby once it has reached `streaming` state.

If primary restarts while commits are waiting for acknowledgement, those waiting transactions will be marked fully committed once the primary database recovers. There is no way to be certain that all standbys have received all outstanding WAL data at time of the crash of the primary. Some transactions may not show as committed on the standby, even though they show as committed on the primary. The guarantee we offer is that the application will not receive explicit acknowledgement of the successful commit of a transaction until the WAL data is known to be safely received by the standby.

If you really do lose your last standby server then you should disable `synchronous_standby_names` and reload the configuration file on the primary server.

If the primary is isolated from remaining standby servers you should fail over to the best candidate of those other remaining standby servers.

If you need to re-create a standby server while transactions are waiting, make sure that the commands pg_start_backup() and pg_stop_backup() are run in a session with `synchronous_commit = off`, otherwise those requests will wait forever for the standby to appear.

25.3. Failover

If the primary server fails then the standby server should begin failover procedures.

If the standby server fails then no failover need take place. If the standby server can be restarted, even some time later, then the recovery process can also be restarted immediately, taking advantage of restartable recovery. If the standby server cannot be restarted, then a full new standby server instance should be created.

If the primary server fails and the standby server becomes the new primary, and then the old primary restarts, you must have a mechanism for informing the old primary that it is no longer the primary. This is sometimes known as STONITH (Shoot The Other Node In The Head), which is necessary to avoid situations where both systems think they are the primary, which will lead to confusion and ultimately data loss.

Many failover systems use just two systems, the primary and the standby, connected by some kind of heartbeat mechanism to continually verify the connectivity between the two and the viability of the primary. It is also possible to use a third system (called a witness server) to prevent some cases of inappropriate failover, but the additional complexity might not be worthwhile unless it is set up with sufficient care and rigorous testing.

PostgreSQL does not provide the system software required to identify a failure on the primary and notify the standby database server. Many such tools exist and are well integrated with the operating system facilities required for successful failover, such as IP address migration.

Once failover to the standby occurs, there is only a single server in operation. This is known as a degenerate state. The former standby is now the primary, but the former primary is down and might stay down. To return to normal operation, a standby server must be recreated, either on the former primary system when it comes up, or on a third, possibly new, system. Once complete, the primary and standby can be considered to have switched roles. Some people choose to use a third server to provide backup for the new primary until the new standby server is recreated, though clearly this complicates the system configuration and operational processes.

So, switching from primary to standby server can be fast but requires some time to re-prepare the failover cluster. Regular switching from primary to standby is useful, since it allows regular downtime on each system for maintenance. This also serves as a test of the failover mechanism to ensure that it will really work when you need it. Written administration procedures are advised.

To trigger failover of a log-shipping standby server, run `pg_ctl promote` or create a trigger file with the file name and path specified by the `trigger_file` setting in `recovery.conf`. If you're planning to use `pg_ctl promote` to fail over, `trigger_file` is not required. If you're setting up the reporting servers that are only used to offload read-only queries from the primary, not for high availability purposes, you don't need to promote it.

25.4. Alternative Method for Log Shipping

An alternative to the built-in standby mode described in the previous sections is to use a `restore_command` that polls the archive location. This was the only option available in versions 8.4 and below. In this setup, set `standby_mode` off, because you are implementing the polling required for standby operation yourself. See the pg_standby module for a reference implementation of this.

Note that in this mode, the server will apply WAL one file at a time, so if you use the standby server for queries (see Hot Standby), there is a delay between an action in the master and when the action becomes visible in the standby, corresponding the time it takes to fill up the WAL file. `archive_timeout` can be used to make that delay shorter. Also note that you can't combine streaming replication with this method.

The operations that occur on both primary and standby servers are normal continuous archiving and recovery tasks. The only point of contact between the two database servers is the archive of WAL files that both share: primary writing to the archive, standby reading from the archive. Care must be taken to ensure that WAL archives from separate primary servers do not become mixed together or confused. The archive need not be large if it is only required for standby operation.

The magic that makes the two loosely coupled servers work together is simply a `restore_command` used on the standby that, when asked for the next WAL file, waits for it to become available from the primary. The `restore_command` is specified in the `recovery.conf` file on the standby server. Normal recovery processing would request a file from the WAL archive, reporting failure if the file was unavailable. For standby processing it is normal for the next WAL file to be unavailable, so the standby must wait for it to appear. For files ending in `.backup` or `.history` there is no need to wait, and a non-zero return code must be returned. A waiting `restore_command` can be written as a custom script that loops after polling for the existence of the next WAL file. There must also be some way to trigger failover, which should interrupt the `restore_command`, break the loop and return a file-not-found error to the standby server. This ends recovery and the standby will then come up as a normal server.

Pseudocode for a suitable `restore_command` is:

```
triggered = false;
while (!NextWALFileReady() && !triggered)
{
    sleep(100000L);         /* wait for ~0.1 sec */
    if (CheckForExternalTrigger())
        triggered = true;
}
if (!triggered)
        CopyWALFileForRecovery();
```

A working example of a waiting `restore_command` is provided in the pg_standby module. It should be used as a reference on how to correctly implement the logic described above. It can also be extended as needed to support specific configurations and environments.

The method for triggering failover is an important part of planning and design. One potential option is the `restore_command` command. It is executed once for each WAL file, but the process running the `restore_command` is created and dies for each file, so there is no daemon or server process, and signals or a signal handler cannot be used. Therefore, the `restore_command` is not suitable to trigger failover. It is possible to use a simple timeout facility, especially if used in conjunction with a known `archive_timeout` setting on the primary. However, this is somewhat error prone since a network problem or busy primary server might be sufficient to initiate failover. A notification mechanism such as the explicit creation of a trigger file is ideal, if this can be arranged.

25.4.1. Implementation

The short procedure for configuring a standby server using this alternative method is as follows. For full details of each step, refer to previous sections as noted.

1. Set up primary and standby systems as nearly identical as possible, including two identical copies of PostgreSQL at the same release level.
2. Set up continuous archiving from the primary to a WAL archive directory on the standby server. Ensure that archive_mode, archive_command and archive_timeout are set appropriately on the primary (see Section 24.3.1).
3. Make a base backup of the primary server (see Section 24.3.2), and load this data onto the standby.
4. Begin recovery on the standby server from the local WAL archive, using a `recovery.conf` that specifies a `restore_command` that waits as described previously (see Section 24.3.4).

Recovery treats the WAL archive as read-only, so once a WAL file has been copied to the standby system it can be copied to tape at the same time as it is being read by the standby database server. Thus, running a standby server for high availability can be performed at the same time as files are stored for longer term disaster recovery purposes.

For testing purposes, it is possible to run both primary and standby servers on the same system. This does not provide any worthwhile improvement in server robustness, nor would it be described as HA.

25.4.2. Record-based Log Shipping

It is also possible to implement record-based log shipping using this alternative method, though this requires custom development, and changes will still only become visible to hot standby queries after a full WAL file has been shipped.

An external program can call the `pg_xlogfile_name_offset()` function (see Section 9.26) to find out the file name and the exact byte offset within it of the current end of WAL. It can then access the WAL file directly and copy the data from the last known end of WAL through the current end over to the standby servers. With this approach, the window for data loss is the polling cycle time of the copying program, which can be very small, and there is no wasted bandwidth from forcing partially-used segment files to be archived. Note that the standby servers' `restore_command` scripts can only deal with whole WAL files, so the incrementally copied data is not ordinarily made available to the standby servers. It is of use only when the primary dies — then the last partial WAL file is fed to the standby before allowing it to come up. The correct implementation of this process requires cooperation of the `restore_command` script with the data copying program.

Starting with PostgreSQL version 9.0, you can use streaming replication (see Section 25.2.5) to achieve the same benefits with less effort.

25.5. Hot Standby

Hot Standby is the term used to describe the ability to connect to the server and run read-only queries while the server is in archive recovery or standby mode. This is useful both for replication purposes and for restoring a backup to a desired state with great precision. The term Hot Standby also refers to the ability of the server to move from recovery through to normal operation while users continue running queries and/or keep their connections open.

Running queries in hot standby mode is similar to normal query operation, though there are several usage and administrative differences explained below.

25.5.1. User's Overview

When the hot_standby parameter is set to true on a standby server, it will begin accepting connections once the recovery has brought the system to a consistent state. All such connections are strictly read-only; not even temporary tables may be written.

The data on the standby takes some time to arrive from the primary server so there will be a measurable delay between primary and standby. Running the same query nearly simultaneously on both primary and standby might therefore return differing results. We say that data on the standby is *eventually consistent* with the primary. Once the commit record for a transaction is replayed on the standby, the changes made by that transaction will be visible to any new snapshots taken on the standby. Snapshots may be taken at the start of each query or at the start of each transaction, depending on the current transaction isolation level. For more details, see Section 13.2.

Transactions started during hot standby may issue the following commands:

- Query access - `SELECT`, `COPY TO`
- Cursor commands - `DECLARE`, `FETCH`, `CLOSE`
- Parameters - `SHOW`, `SET`, `RESET`
- Transaction management commands

    - BEGIN, END, ABORT, START TRANSACTION
    - SAVEPOINT, RELEASE, ROLLBACK TO SAVEPOINT
    - EXCEPTION blocks and other internal subtransactions
- LOCK TABLE, though only when explicitly in one of these modes: ACCESS SHARE, ROW SHARE or ROW EXCLUSIVE.
- Plans and resources - PREPARE, EXECUTE, DEALLOCATE, DISCARD
- Plugins and extensions - LOAD

Transactions started during hot standby will never be assigned a transaction ID and cannot write to the system write-ahead log. Therefore, the following actions will produce error messages:

- Data Manipulation Language (DML) - INSERT, UPDATE, DELETE, COPY FROM, TRUNCATE. Note that there are no allowed actions that result in a trigger being executed during recovery. This restriction applies even to temporary tables, because table rows cannot be read or written without assigning a transaction ID, which is currently not possible in a Hot Standby environment.
- Data Definition Language (DDL) - CREATE, DROP, ALTER, COMMENT. This restriction applies even to temporary tables, because carrying out these operations would require updating the system catalog tables.
- SELECT ... FOR SHARE | UPDATE, because row locks cannot be taken without updating the underlying data files.
- Rules on SELECT statements that generate DML commands.
- LOCK that explicitly requests a mode higher than ROW EXCLUSIVE MODE.
- LOCK in short default form, since it requests ACCESS EXCLUSIVE MODE.
- Transaction management commands that explicitly set non-read-only state:
    - BEGIN READ WRITE, START TRANSACTION READ WRITE
    - SET TRANSACTION READ WRITE, SET SESSION CHARACTERISTICS AS TRANSACTION READ WRITE
    - SET transaction_read_only = off
- Two-phase commit commands - PREPARE TRANSACTION, COMMIT PREPARED, ROLLBACK PREPARED because even read-only transactions need to write WAL in the prepare phase (the first phase of two phase commit).
- Sequence updates - nextval(), setval()
- LISTEN, UNLISTEN, NOTIFY

In normal operation, “read-only” transactions are allowed to update sequences and to use LISTEN, UNLISTEN, and NOTIFY, so Hot Standby sessions operate under slightly tighter restrictions than ordinary read-only sessions. It is possible that some of these restrictions might be loosened in a future release.

During hot standby, the parameter transaction_read_only is always true and may not be changed. But as long as no attempt is made to modify the database, connections during hot standby will act much like any other database connection. If failover or switchover occurs, the database will switch to normal processing mode. Sessions will remain connected while the server changes mode.

Once hot standby finishes, it will be possible to initiate read-write transactions (even from a session begun during hot standby).

Users will be able to tell whether their session is read-only by issuing `SHOW transaction_read_only`. In addition, a set of functions (Table 9-66) allow users to access information about the standby server. These allow you to write programs that are aware of the current state of the database. These can be used to monitor the progress of recovery, or to allow you to write complex programs that restore the database to particular states.

25.5.2. Handling Query Conflicts

The primary and standby servers are in many ways loosely connected. Actions on the primary will have an effect on the standby. As a result, there is potential for negative interactions or conflicts between them. The easiest conflict to understand is performance: if a huge data load is taking place on the primary then this will generate a similar stream of WAL records on the standby, so standby queries may contend for system resources, such as I/O.

There are also additional types of conflict that can occur with Hot Standby. These conflicts are *hard conflicts* in the sense that queries might need to be canceled and, in some cases, sessions disconnected to resolve them. The user is provided with several ways to handle these conflicts. Conflict cases include:

- Access Exclusive locks taken on the primary server, including both explicit `LOCK` commands and various DDL actions, conflict with table accesses in standby queries.
- Dropping a tablespace on the primary conflicts with standby queries using that tablespace for temporary work files.
- Dropping a database on the primary conflicts with sessions connected to that database on the standby.
- Application of a vacuum cleanup record from WAL conflicts with standby transactions whose snapshots can still “see” any of the rows to be removed.
- Application of a vacuum cleanup record from WAL conflicts with queries accessing the target page on the standby, whether or not the data to be removed is visible.

On the primary server, these cases simply result in waiting; and the user might choose to cancel either of the conflicting actions. However, on the standby there is no choice: the WAL-logged action already occurred on the primary so the standby must not fail to apply it. Furthermore, allowing WAL application to wait indefinitely may be very undesirable, because the standby’s state will become increasingly far behind the primary’s. Therefore, a mechanism is provided to forcibly cancel standby queries that conflict with to-be-applied WAL records.

An example of the problem situation is an administrator on the primary server running `DROP TABLE` on a table that is currently being queried on the standby server. Clearly the standby query cannot continue if the `DROP TABLE` is applied on the standby. If this situation occurred on the primary, the `DROP TABLE` would wait until the other query had finished. But when `DROP TABLE` is run on the primary, the primary doesn’t have information about what queries are running on the standby, so it will not wait for any such standby queries. The WAL change records come through to the standby while the standby query is still running, causing a conflict. The standby server must either delay application of the WAL records (and everything after them, too) or else cancel the conflicting query so that the `DROP TABLE` can be applied.

When a conflicting query is short, it's typically desirable to allow it to complete by delaying WAL application for a little bit; but a long delay in WAL application is usually not desirable. So the cancel mechanism has parameters, max_standby_archive_delay and max_standby_streaming_delay, that define the maximum allowed delay in WAL application. Conflicting queries will be canceled once it has taken longer than the relevant delay setting to apply any newly-received WAL data. There are two parameters so that different delay values can be specified for the case of reading WAL data from an archive (i.e., initial recovery from a base backup or "catching up" a standby server that has fallen far behind) versus reading WAL data via streaming replication.

In a standby server that exists primarily for high availability, it's best to set the delay parameters relatively short, so that the server cannot fall far behind the primary due to delays caused by standby queries. However, if the standby server is meant for executing long-running queries, then a high or even infinite delay value may be preferable. Keep in mind however that a long-running query could cause other sessions on the standby server to not see recent changes on the primary, if it delays application of WAL records.

Once the delay specified by `max_standby_archive_delay` or `max_standby_streaming_delay` has been exceeded, conflicting queries will be canceled. This usually results just in a cancellation error, although in the case of replaying a `DROP DATABASE` the entire conflicting session will be terminated. Also, if the conflict is over a lock held by an idle transaction, the conflicting session is terminated (this behavior might change in the future).

Canceled queries may be retried immediately (after beginning a new transaction, of course). Since query cancellation depends on the nature of the WAL records being replayed, a query that was canceled may well succeed if it is executed again.

Keep in mind that the delay parameters are compared to the elapsed time since the WAL data was received by the standby server. Thus, the grace period allowed to any one query on the standby is never more than the delay parameter, and could be considerably less if the standby has already fallen behind as a result of waiting for previous queries to complete, or as a result of being unable to keep up with a heavy update load.

The most common reason for conflict between standby queries and WAL replay is "early cleanup". Normally, PostgreSQL allows cleanup of old row versions when there are no transactions that need to see them to ensure correct visibility of data according to MVCC rules. However, this rule can only be applied for transactions executing on the master. So it is possible that cleanup on the master will remove row versions that are still visible to a transaction on the standby.

Experienced users should note that both row version cleanup and row version freezing will potentially conflict with standby queries. Running a manual `VACUUM FREEZE` is likely to cause conflicts even on tables with no updated or deleted rows.

Users should be clear that tables that are regularly and heavily updated on the primary server will quickly cause cancellation of longer running queries on the standby. In such cases the setting of a finite value for `max_standby_archive_delay` or `max_standby_streaming_delay` can be considered similar to setting `statement_timeout`.

Remedial possibilities exist if the number of standby-query cancellations is found to be unacceptable. The first option is to set the parameter `hot_standby_feedback`, which prevents `VACUUM` from removing recently-dead rows and so cleanup conflicts do not occur. If you do this, you should note that this will delay cleanup of dead rows on the primary, which may result in undesirable table bloat. However, the cleanup situation will be no worse than if the standby queries were running directly on the primary server, and you are still getting the benefit of off-loading execution onto the standby. If standby servers connect and disconnect frequently, you might want to make adjustments to handle the period when `hot_standby_feedback` feedback is not being provided. For example, consider increasing `max_standby_archive_delay` so that queries are not rapidly canceled

by conflicts in WAL archive files during disconnected periods. You should also consider increasing max_standby_streaming_delay to avoid rapid cancellations by newly-arrived streaming WAL entries after reconnection.

Another option is to increase vacuum_defer_cleanup_age on the primary server, so that dead rows will not be cleaned up as quickly as they normally would be. This will allow more time for queries to execute before they are canceled on the standby, without having to set a high max_standby_streaming_delay. However it is difficult to guarantee any specific execution-time window with this approach, since vacuum_defer_cleanup_age is measured in transactions executed on the primary server.

The number of query cancels and the reason for them can be viewed using the pg_stat_database_conflicts system view on the standby server. The pg_stat_database system view also contains summary information.

25.5.3. Administrator's Overview

If hot_standby is turned on in postgresql.conf and there is a recovery.conf file present, the server will run in Hot Standby mode. However, it may take some time for Hot Standby connections to be allowed, because the server will not accept connections until it has completed sufficient recovery to provide a consistent state against which queries can run. During this period, clients that attempt to connect will be refused with an error message. To confirm the server has come up, either loop trying to connect from the application, or look for these messages in the server logs:

```
LOG:  entering standby mode

... then some time later ...

LOG:  consistent recovery state reached
LOG:  database system is ready to accept read only connections
```

Consistency information is recorded once per checkpoint on the primary. It is not possible to enable hot standby when reading WAL written during a period when wal_level was not set to hot_standby or logical on the primary. Reaching a consistent state can also be delayed in the presence of both of these conditions:

- A write transaction has more than 64 subtransactions
- Very long-lived write transactions

If you are running file-based log shipping ("warm standby"), you might need to wait until the next WAL file arrives, which could be as long as the archive_timeout setting on the primary.

The setting of some parameters on the standby will need reconfiguration if they have been changed on the primary. For these parameters, the value on the standby must be equal to or greater than the value on the primary. If these parameters are not set high enough then the standby will refuse to start. Higher values can then be supplied and the server restarted to begin recovery again. These parameters are:

- max_connections
- max_prepared_transactions
- max_locks_per_transaction

It is important that the administrator select appropriate settings for max_standby_archive_delay and max_standby_streaming_delay. The best choices vary depending on business priorities. For example if the server is primarily tasked as a High Availability server, then you will want low delay settings, perhaps even zero, though that is a very aggressive setting. If the standby server is tasked as an additional server for decision support queries then it might be acceptable to set the maximum delay values to many hours, or even -1 which means wait forever for queries to complete.

Transaction status "hint bits" written on the primary are not WAL-logged, so data on the standby will likely re-write the hints again on the standby. Thus, the standby server will still perform disk writes even though all users are read-only; no changes occur to the data values themselves. Users will still write large sort temporary files and re-generate relcache info files, so no part of the database is truly read-only during hot standby mode. Note also that writes to remote databases using dblink module, and other operations outside the database using PL functions will still be possible, even though the transaction is read-only locally.

The following types of administration commands are not accepted during recovery mode:

- Data Definition Language (DDL) - e.g. `CREATE INDEX`
- Privilege and Ownership - `GRANT`, `REVOKE`, `REASSIGN`
- Maintenance commands - `ANALYZE`, `VACUUM`, `CLUSTER`, `REINDEX`

Again, note that some of these commands are actually allowed during "read only" mode transactions on the primary.

As a result, you cannot create additional indexes that exist solely on the standby, nor statistics that exist solely on the standby. If these administration commands are needed, they should be executed on the primary, and eventually those changes will propagate to the standby.

`pg_cancel_backend()` and `pg_terminate_backend()` will work on user backends, but not the Startup process, which performs recovery. `pg_stat_activity` does not show an entry for the Startup process, nor do recovering transactions show as active. As a result, `pg_prepared_xacts` is always empty during recovery. If you wish to resolve in-doubt prepared transactions, view `pg_prepared_xacts` on the primary and issue commands to resolve transactions there.

`pg_locks` will show locks held by backends, as normal. `pg_locks` also shows a virtual transaction managed by the Startup process that owns all `AccessExclusiveLocks` held by transactions being replayed by recovery. Note that the Startup process does not acquire locks to make database changes, and thus locks other than `AccessExclusiveLocks` do not show in `pg_locks` for the Startup process; they are just presumed to exist.

The Nagios plugin check_pgsql will work, because the simple information it checks for exists. The check_postgres monitoring script will also work, though some reported values could give different or confusing results. For example, last vacuum time will not be maintained, since no vacuum occurs on the standby. Vacuums running on the primary do still send their changes to the standby.

WAL file control commands will not work during recovery, e.g. `pg_start_backup`, `pg_switch_xlog` etc.

Dynamically loadable modules work, including `pg_stat_statements`.

Advisory locks work normally in recovery, including deadlock detection. Note that advisory locks are never WAL logged, so it is impossible for an advisory lock on either the primary or the standby to conflict with WAL replay. Nor is it possible to acquire an advisory lock on the primary and have it

initiate a similar advisory lock on the standby. Advisory locks relate only to the server on which they are acquired.

Trigger-based replication systems such as Slony, Londiste and Bucardo won't run on the standby at all, though they will run happily on the primary server as long as the changes are not sent to standby servers to be applied. WAL replay is not trigger-based so you cannot relay from the standby to any system that requires additional database writes or relies on the use of triggers.

New OIDs cannot be assigned, though some UUID generators may still work as long as they do not rely on writing new status to the database.

Currently, temporary table creation is not allowed during read only transactions, so in some cases existing scripts will not run correctly. This restriction might be relaxed in a later release. This is both a SQL Standard compliance issue and a technical issue.

`DROP TABLESPACE` can only succeed if the tablespace is empty. Some standby users may be actively using the tablespace via their `temp_tablespaces` parameter. If there are temporary files in the tablespace, all active queries are canceled to ensure that temporary files are removed, so the tablespace can be removed and WAL replay can continue.

Running `DROP DATABASE` or `ALTER DATABASE ... SET TABLESPACE` on the primary will generate a WAL entry that will cause all users connected to that database on the standby to be forcibly disconnected. This action occurs immediately, whatever the setting of `max_standby_streaming_delay`. Note that `ALTER DATABASE ... RENAME` does not disconnect users, which in most cases will go unnoticed, though might in some cases cause a program confusion if it depends in some way upon database name.

In normal (non-recovery) mode, if you issue `DROP USER` or `DROP ROLE` for a role with login capability while that user is still connected then nothing happens to the connected user - they remain connected. The user cannot reconnect however. This behavior applies in recovery also, so a `DROP USER` on the primary does not disconnect that user on the standby.

The statistics collector is active during recovery. All scans, reads, blocks, index usage, etc., will be recorded normally on the standby. Replayed actions will not duplicate their effects on primary, so replaying an insert will not increment the Inserts column of pg_stat_user_tables. The stats file is deleted at the start of recovery, so stats from primary and standby will differ; this is considered a feature, not a bug.

Autovacuum is not active during recovery. It will start normally at the end of recovery.

The background writer is active during recovery and will perform restartpoints (similar to checkpoints on the primary) and normal block cleaning activities. This can include updates of the hint bit information stored on the standby server. The `CHECKPOINT` command is accepted during recovery, though it performs a restartpoint rather than a new checkpoint.

25.5.4. Hot Standby Parameter Reference

Various parameters have been mentioned above in Section 25.5.2 and Section 25.5.3.

On the primary, parameters wal_level and vacuum_defer_cleanup_age can be used. max_standby_archive_delay and max_standby_streaming_delay have no effect if set on the primary.

On the standby, parameters hot_standby, max_standby_archive_delay and max_standby_streaming_delay can be used. vacuum_defer_cleanup_age has no effect as long as the server remains in standby mode, though it will become relevant if the standby becomes primary.

25.5.5. Caveats

There are several limitations of Hot Standby. These can and probably will be fixed in future releases:

- Operations on hash indexes are not presently WAL-logged, so replay will not update these indexes.
- Full knowledge of running transactions is required before snapshots can be taken. Transactions that use large numbers of subtransactions (currently greater than 64) will delay the start of read only connections until the completion of the longest running write transaction. If this situation occurs, explanatory messages will be sent to the server log.
- Valid starting points for standby queries are generated at each checkpoint on the master. If the standby is shut down while the master is in a shutdown state, it might not be possible to re-enter Hot Standby until the primary is started up, so that it generates further starting points in the WAL logs. This situation isn't a problem in the most common situations where it might happen. Generally, if the primary is shut down and not available anymore, that's likely due to a serious failure that requires the standby being converted to operate as the new primary anyway. And in situations where the primary is being intentionally taken down, coordinating to make sure the standby becomes the new primary smoothly is also standard procedure.
- At the end of recovery, `AccessExclusiveLocks` held by prepared transactions will require twice the normal number of lock table entries. If you plan on running either a large number of concurrent prepared transactions that normally take `AccessExclusiveLocks`, or you plan on having one large transaction that takes many `AccessExclusiveLocks`, you are advised to select a larger value of `max_locks_per_transaction`, perhaps as much as twice the value of the parameter on the primary server. You need not consider this at all if your setting of `max_prepared_transactions` is 0.
- The Serializable transaction isolation level is not yet available in hot standby. (See Section 13.2.3 and Section 13.4.1 for details.) An attempt to set a transaction to the serializable isolation level in hot standby mode will generate an error.

Chapter 26. Recovery Configuration

This chapter describes the settings available in the `recovery.conf` file. They apply only for the duration of the recovery. They must be reset for any subsequent recovery you wish to perform. They cannot be changed once recovery has begun.

Settings in `recovery.conf` are specified in the format `name = 'value'`. One parameter is specified per line. Hash marks (`#`) designate the rest of the line as a comment. To embed a single quote in a parameter value, write two quotes (`''`).

A sample file, `share/recovery.conf.sample`, is provided in the installation's `share/` directory.

26.1. Archive Recovery Settings

`restore_command` (`string`)

The local shell command to execute to retrieve an archived segment of the WAL file series. This parameter is required for archive recovery, but optional for streaming replication. Any `%f` in the string is replaced by the name of the file to retrieve from the archive, and any `%p` is replaced by the copy destination path name on the server. (The path name is relative to the current working directory, i.e., the cluster's data directory.) Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be kept to allow a restore to be restartable, so this information can be used to truncate the archive to just the minimum required to support restarting from the current restore. `%r` is typically only used by warm-standby configurations (see Section 25.2). Write `%%` to embed an actual `%` character.

It is important for the command to return a zero exit status only if it succeeds. The command *will* be asked for file names that are not present in the archive; it must return nonzero when so asked. Examples:

```
restore_command = 'cp /mnt/server/archivedir/%f "%p"'
restore_command = 'copy "C:\\server\\archivedir\\%f" "%p"'  # Windows
```

An exception is that if the command was terminated by a signal (other than SIGTERM, which is used as part of a database server shutdown) or an error by the shell (such as command not found), then recovery will abort and the server will not start up.

`archive_cleanup_command` (`string`)

This optional parameter specifies a shell command that will be executed at every restartpoint. The purpose of `archive_cleanup_command` is to provide a mechanism for cleaning up old archived WAL files that are no longer needed by the standby server. Any `%r` is replaced by the name of the file containing the last valid restart point. That is the earliest file that must be *kept* to allow a restore to be restartable, and so all files earlier than `%r` may be safely removed. This information can be used to truncate the archive to just the minimum required to support restart from the current restore. The pg_archivecleanup module is often used in `archive_cleanup_command` for single-standby configurations, for example:

```
archive_cleanup_command = 'pg_archivecleanup /mnt/server/archivedir %r'
```

Note however that if multiple standby servers are restoring from the same archive directory, you will need to ensure that you do not delete WAL files until they are no longer needed by any of the servers. `archive_cleanup_command` would typically be used in a warm-standby configuration (see Section 25.2). Write `%%` to embed an actual `%` character in the command.

If the command returns a nonzero exit status then a warning log message will be written. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), a fatal error will be raised.

`recovery_end_command` (`string`)

This parameter specifies a shell command that will be executed once only at the end of recovery. This parameter is optional. The purpose of the `recovery_end_command` is to provide a mechanism for cleanup following replication or recovery. Any `%r` is replaced by the name of the file containing the last valid restart point, like in archive_cleanup_command.

If the command returns a nonzero exit status then a warning log message will be written and the database will proceed to start up anyway. An exception is that if the command was terminated by a signal or an error by the shell (such as command not found), the database will not proceed with startup.

26.2. Recovery Target Settings

By default, recovery will recover to the end of the WAL log. The following parameters can be used to specify an earlier stopping point. At most one of `recovery_target`, `recovery_target_name`, `recovery_target_time`, or `recovery_target_xid` can be used; if more than one of these is specified in the configuration file, the last entry will be used.

`recovery_target = 'immediate'`

This parameter specifies that recovery should end as soon as a consistent state is reached, i.e. as early as possible. When restoring from an online backup, this means the point where taking the backup ended.

Technically, this is a string parameter, but `'immediate'` is currently the only allowed value.

`recovery_target_name` (`string`)

This parameter specifies the named restore point (created with `pg_create_restore_point()`) to which recovery will proceed.

`recovery_target_time` (`timestamp`)

This parameter specifies the time stamp up to which recovery will proceed. The precise stopping point is also influenced by recovery_target_inclusive.

`recovery_target_xid` (`string`)

This parameter specifies the transaction ID up to which recovery will proceed. Keep in mind that while transaction IDs are assigned sequentially at transaction start, transactions can complete in a different numeric order. The transactions that will be recovered are those that committed before (and optionally including) the specified one. The precise stopping point is also influenced by recovery_target_inclusive.

The following options further specify the recovery target, and affect what happens when the target is reached:

`recovery_target_inclusive` (`boolean`)

Specifies whether to stop just after the specified recovery target (`true`), or just before the recovery target (`false`). Applies when either recovery_target_time or recovery_target_xid is specified. This setting controls whether transactions having exactly the target commit time or ID, respectively, will be included in the recovery. Default is `true`.

recovery_target_timeline (string)

Specifies recovering into a particular timeline. The default is to recover along the same timeline that was current when the base backup was taken. Setting this to latest recovers to the latest timeline found in the archive, which is useful in a standby server. Other than that you only need to set this parameter in complex re-recovery situations, where you need to return to a state that itself was reached after a point-in-time recovery. See Section 24.3.5 for discussion.

pause_at_recovery_target (boolean)

Specifies whether recovery should pause when the recovery target is reached. The default is true. This is intended to allow queries to be executed against the database to check if this recovery target is the most desirable point for recovery. The paused state can be resumed by using pg_xlog_replay_resume() (see Table 9-67), which then causes recovery to end. If this recovery target is not the desired stopping point, then shut down the server, change the recovery target settings to a later target and restart to continue recovery.

This setting has no effect if hot_standby is not enabled, or if no recovery target is set.

26.3. Standby Server Settings

standby_mode (boolean)

Specifies whether to start the PostgreSQL server as a standby. If this parameter is on, the server will not stop recovery when the end of archived WAL is reached, but will keep trying to continue recovery by fetching new WAL segments using restore_command and/or by connecting to the primary server as specified by the primary_conninfo setting.

primary_conninfo (string)

Specifies a connection string to be used for the standby server to connect with the primary. This string is in the format described in Section 31.1.1. If any option is unspecified in this string, then the corresponding environment variable (see Section 31.14) is checked. If the environment variable is not set either, then defaults are used.

The connection string should specify the host name (or address) of the primary server, as well as the port number if it is not the same as the standby server's default. Also specify a user name corresponding to a suitably-privileged role on the primary (see Section 25.2.5.1). A password needs to be provided too, if the primary demands password authentication. It can be provided in the primary_conninfo string, or in a separate ~/.pgpass file on the standby server (use replication as the database name). Do not specify a database name in the primary_conninfo string.

This setting has no effect if standby_mode is off.

primary_slot_name (string)

Optionally specifies an existing replication slot to be used when connecting to the primary via streaming replication to control resource removal on the upstream node (see Section 25.2.6). This setting has no effect if primary_conninfo is not set.

trigger_file (string)

Specifies a trigger file whose presence ends recovery in the standby. Even if this value is not set, you can still promote the standby using pg_ctl promote. This setting has no effect if standby_mode is off.

`recovery_min_apply_delay` (`integer`)

By default, a standby server restores WAL records from the primary as soon as possible. It may be useful to have a time-delayed copy of the data, offering opportunities to correct data loss errors. This parameter allows you to delay recovery by a fixed period of time, measured in milliseconds if no unit is specified. For example, if you set this parameter to `5min`, the standby will replay each transaction commit only when the system time on the standby is at least five minutes past the commit time reported by the master.

It is possible that the replication delay between servers exceeds the value of this parameter, in which case no delay is added. Note that the delay is calculated between the WAL timestamp as written on master and the current time on the standby. Delays in transfer because of network lag or cascading replication configurations may reduce the actual wait time significantly. If the system clocks on master and standby are not synchronized, this may lead to recovery applying records earlier than expected; but that is not a major issue because useful settings of this parameter are much larger than typical time deviations between servers.

The delay occurs only on WAL records for transaction commits. Other records are replayed as quickly as possible, which is not a problem because MVCC visibility rules ensure their effects are not visible until the corresponding commit record is applied.

The delay occurs until the standby is promoted or triggered. After that the standby will end recovery without further waiting.

This parameter is intended for use with streaming replication deployments; however, if the parameter is specified it will be honored in all cases. Synchronous replication is not affected by this setting because there is not yet any setting to request synchronous apply of transaction commits. `hot_standby_feedback` will be delayed by use of this feature which could lead to bloat on the master; use both together with care.

Chapter 27. Monitoring Database Activity

A database administrator frequently wonders, "What is the system doing right now?" This chapter discusses how to find that out.

Several tools are available for monitoring database activity and analyzing performance. Most of this chapter is devoted to describing PostgreSQL's statistics collector, but one should not neglect regular Unix monitoring programs such as `ps`, `top`, `iostat`, and `vmstat`. Also, once one has identified a poorly-performing query, further investigation might be needed using PostgreSQL's EXPLAIN command. Section 14.1 discusses `EXPLAIN` and other methods for understanding the behavior of an individual query.

27.1. Standard Unix Tools

On most Unix platforms, PostgreSQL modifies its command title as reported by `ps`, so that individual server processes can readily be identified. A sample display is

```
$ ps auxww | grep ^postgres
postgres  15551  0.0  0.1  57536  7132 pts/0    S    18:02   0:00 postgres -i
postgres  15554  0.0  0.0  57536  1184 ?        Ss   18:02   0:00 postgres: writer proce
postgres  15555  0.0  0.0  57536   916 ?        Ss   18:02   0:00 postgres: checkpointer
postgres  15556  0.0  0.0  57536   916 ?        Ss   18:02   0:00 postgres: wal writer p
postgres  15557  0.0  0.0  58504  2244 ?        Ss   18:02   0:00 postgres: autovacuum l
postgres  15558  0.0  0.0  17512  1068 ?        Ss   18:02   0:00 postgres: stats collec
postgres  15582  0.0  0.0  58772  3080 ?        Ss   18:04   0:00 postgres: joe runbug 1
postgres  15606  0.0  0.0  58772  3052 ?        Ss   18:07   0:00 postgres: tgl regressi
postgres  15610  0.0  0.0  58772  3056 ?        Ss   18:07   0:00 postgres: tgl regressi
```

(The appropriate invocation of `ps` varies across different platforms, as do the details of what is shown. This example is from a recent Linux system.) The first process listed here is the master server process. The command arguments shown for it are the same ones used when it was launched. The next five processes are background worker processes automatically launched by the master process. (The "stats collector" process will not be present if you have set the system not to start the statistics collector; likewise the "autovacuum launcher" process can be disabled.) Each of the remaining processes is a server process handling one client connection. Each such process sets its command line display in the form

`postgres:` *`user database host activity`*

The user, database, and (client) host items remain the same for the life of the client connection, but the activity indicator changes. The activity can be `idle` (i.e., waiting for a client command), `idle in transaction` (waiting for client inside a `BEGIN` block), or a command type name such as `SELECT`. Also, `waiting` is appended if the server process is presently waiting on a lock held by another session. In the above example we can infer that process 15606 is waiting for process 15610 to complete its transaction and thereby release some lock. (Process 15610 must be the blocker, because there is no other active session. In more complicated cases it would be necessary to look into the `pg_locks` system view to determine who is blocking whom.)

If you have turned off update_process_title then the activity indicator is not updated; the process title is set only once when a new process is launched. On some platforms this saves a measurable amount of per-command overhead; on others it's insignificant.

Tip: Solaris requires special handling. You must use `/usr/ucb/ps`, rather than `/bin/ps`. You also must use two `w` flags, not just one. In addition, your original invocation of the `postgres` command must have a shorter `ps` status display than that provided by each server process. If you fail to do all three things, the `ps` output for each server process will be the original `postgres` command line.

27.2. The Statistics Collector

PostgreSQL's *statistics collector* is a subsystem that supports collection and reporting of information about server activity. Presently, the collector can count accesses to tables and indexes in both disk-block and individual-row terms. It also tracks the total number of rows in each table, and information about vacuum and analyze actions for each table. It can also count calls to user-defined functions and the total time spent in each one.

PostgreSQL also supports reporting of the exact command currently being executed by other server processes. This facility is independent of the collector process.

27.2.1. Statistics Collection Configuration

Since collection of statistics adds some overhead to query execution, the system can be configured to collect or not collect information. This is controlled by configuration parameters that are normally set in `postgresql.conf`. (See Chapter 18 for details about setting configuration parameters.)

The parameter track_activities enables monitoring of the current command being executed by any server process.

The parameter track_counts controls whether statistics are collected about table and index accesses.

The parameter track_functions enables tracking of usage of user-defined functions.

The parameter track_io_timing enables monitoring of block read and write times.

Normally these parameters are set in `postgresql.conf` so that they apply to all server processes, but it is possible to turn them on or off in individual sessions using the SET command. (To prevent ordinary users from hiding their activity from the administrator, only superusers are allowed to change these parameters with `SET`.)

The statistics collector transmits the collected information to other PostgreSQL processes through temporary files. These files are stored in the directory named by the stats_temp_directory parameter, `pg_stat_tmp` by default. For better performance, `stats_temp_directory` can be pointed at a RAM-based file system, decreasing physical I/O requirements. When the server shuts down cleanly, a permanent copy of the statistics data is stored in the `pg_stat` subdirectory, so that statistics can be retained across server restarts. When recovery is performed at server start (e.g. after immediate shutdown, server crash, and point-in-time recovery), all statistics counters are reset.

27.2.2. Viewing Collected Statistics

Several predefined views, listed in Table 27-1, are available to show the results of statistics collection. Alternatively, one can build custom views using the underlying statistics functions, as discussed in Section 27.2.3.

When using the statistics to monitor current activity, it is important to realize that the information does not update instantaneously. Each individual server process transmits new statistical counts to

the collector just before going idle; so a query or transaction still in progress does not affect the displayed totals. Also, the collector itself emits a new report at most once per PGSTAT_STAT_INTERVAL milliseconds (500 ms unless altered while building the server). So the displayed information lags behind actual activity. However, current-query information collected by track_activities is always up-to-date.

Another important point is that when a server process is asked to display any of these statistics, it first fetches the most recent report emitted by the collector process and then continues to use this snapshot for all statistical views and functions until the end of its current transaction. So the statistics will show static information as long as you continue the current transaction. Similarly, information about the current queries of all sessions is collected when any such information is first requested within a transaction, and the same information will be displayed throughout the transaction. This is a feature, not a bug, because it allows you to perform several queries on the statistics and correlate the results without worrying that the numbers are changing underneath you. But if you want to see new results with each query, be sure to do the queries outside any transaction block. Alternatively, you can invoke pg_stat_clear_snapshot(), which will discard the current transaction's statistics snapshot (if any). The next use of statistical information will cause a new snapshot to be fetched.

A transaction can also see its own statistics (as yet untransmitted to the collector) in the views pg_stat_xact_all_tables, pg_stat_xact_sys_tables, pg_stat_xact_user_tables, and pg_stat_xact_user_functions. These numbers do not act as stated above; instead they update continuously throughout the transaction.

Table 27-1. Standard Statistics Views

View Name	Description
pg_stat_activity	One row per server process, showing information related to the current activity of that process, such as state and current query. See pg_stat_activity for details.
pg_stat_archiver	One row only, showing statistics about the WAL archiver process's activity. See pg_stat_archiver for details.
pg_stat_bgwriter	One row only, showing statistics about the background writer process's activity. See pg_stat_bgwriter for details.
pg_stat_database	One row per database, showing database-wide statistics. See pg_stat_database for details.
pg_stat_all_tables	One row for each table in the current database, showing statistics about accesses to that specific table. See pg_stat_all_tables for details.
pg_stat_sys_tables	Same as pg_stat_all_tables, except that only system tables are shown.
pg_stat_user_tables	Same as pg_stat_all_tables, except that only user tables are shown.

View Name	Description
pg_stat_xact_all_tables	Similar to pg_stat_all_tables, but counts actions taken so far within the current transaction (which are *not* yet included in pg_stat_all_tables and related views). The columns for numbers of live and dead rows and vacuum and analyze actions are not present in this view.
pg_stat_xact_sys_tables	Same as pg_stat_xact_all_tables, except that only system tables are shown.
pg_stat_xact_user_tables	Same as pg_stat_xact_all_tables, except that only user tables are shown.
pg_stat_all_indexes	One row for each index in the current database, showing statistics about accesses to that specific index. See pg_stat_all_indexes for details.
pg_stat_sys_indexes	Same as pg_stat_all_indexes, except that only indexes on system tables are shown.
pg_stat_user_indexes	Same as pg_stat_all_indexes, except that only indexes on user tables are shown.
pg_statio_all_tables	One row for each table in the current database, showing statistics about I/O on that specific table. See pg_statio_all_tables for details.
pg_statio_sys_tables	Same as pg_statio_all_tables, except that only system tables are shown.
pg_statio_user_tables	Same as pg_statio_all_tables, except that only user tables are shown.
pg_statio_all_indexes	One row for each index in the current database, showing statistics about I/O on that specific index. See pg_statio_all_indexes for details.
pg_statio_sys_indexes	Same as pg_statio_all_indexes, except that only indexes on system tables are shown.
pg_statio_user_indexes	Same as pg_statio_all_indexes, except that only indexes on user tables are shown.
pg_statio_all_sequences	One row for each sequence in the current database, showing statistics about I/O on that specific sequence. See pg_statio_all_sequences for details.
pg_statio_sys_sequences	Same as pg_statio_all_sequences, except that only system sequences are shown. (Presently, no system sequences are defined, so this view is always empty.)
pg_statio_user_sequences	Same as pg_statio_all_sequences, except that only user sequences are shown.
pg_stat_user_functions	One row for each tracked function, showing statistics about executions of that function. See pg_stat_user_functions for details.

View Name	Description
pg_stat_xact_user_functions	Similar to pg_stat_user_functions, but counts only calls during the current transaction (which are *not* yet included in pg_stat_user_functions).
pg_stat_replication	One row per WAL sender process, showing statistics about replication to that sender's connected standby server. See pg_stat_replication for details.
pg_stat_database_conflicts	One row per database, showing database-wide statistics about query cancels due to conflict with recovery on standby servers. See pg_stat_database_conflicts for details.

The per-index statistics are particularly useful to determine which indexes are being used and how effective they are.

The pg_statio_ views are primarily useful to determine the effectiveness of the buffer cache. When the number of actual disk reads is much smaller than the number of buffer hits, then the cache is satisfying most read requests without invoking a kernel call. However, these statistics do not give the entire story: due to the way in which PostgreSQL handles disk I/O, data that is not in the PostgreSQL buffer cache might still reside in the kernel's I/O cache, and might therefore still be fetched without requiring a physical read. Users interested in obtaining more detailed information on PostgreSQL I/O behavior are advised to use the PostgreSQL statistics collector in combination with operating system utilities that allow insight into the kernel's handling of I/O.

Table 27-2. pg_stat_activity View

Column	Type	Description
datid	oid	OID of the database this backend is connected to
datname	name	Name of the database this backend is connected to
pid	integer	Process ID of this backend
usesysid	oid	OID of the user logged into this backend
usename	name	Name of the user logged into this backend
application_name	text	Name of the application that is connected to this backend
client_addr	inet	IP address of the client connected to this backend. If this field is null, it indicates either that the client is connected via a Unix socket on the server machine or that this is an internal process such as autovacuum.

Column	Type	Description
client_hostname	text	Host name of the connected client, as reported by a reverse DNS lookup of client_addr. This field will only be non-null for IP connections, and only when log_hostname is enabled.
client_port	integer	TCP port number that the client is using for communication with this backend, or -1 if a Unix socket is used
backend_start	timestamp with time zone	Time when this process was started, i.e., when the client connected to the server
xact_start	timestamp with time zone	Time when this process' current transaction was started, or null if no transaction is active. If the current query is the first of its transaction, this column is equal to the query_start column.
query_start	timestamp with time zone	Time when the currently active query was started, or if state is not active, when the last query was started
state_change	timestamp with time zone	Time when the state was last changed
waiting	boolean	True if this backend is currently waiting on a lock

Column	Type	Description
state	text	Current overall state of this backend. Possible values are: • active: The backend is executing a query. • idle: The backend is waiting for a new client command. • idle in transaction: The backend is in a transaction, but is not currently executing a query. • idle in transaction (aborted): This state is similar to idle in transaction, except one of the statements in the transaction caused an error. • fastpath function call: The backend is executing a fast-path function. • disabled: This state is reported if track_activities is disabled in this backend.
backend_xid	xid	Top-level transaction identifier of this backend, if any.
backend_xmin	xid	The current backend's xmin horizon.
query	text	Text of this backend's most recent query. If state is active this field shows the currently executing query. In all other states, it shows the last query that was executed.

The pg_stat_activity view will have one row per server process, showing information related to the current activity of that process.

Note: The waiting and state columns are independent. If a backend is in the active state, it may or may not be waiting. If the state is active and waiting is true, it means that a query is being executed, but is being blocked by a lock somewhere in the system.

Table 27-3. `pg_stat_archiver` View

Column	Type	Description
`archived_count`	`bigint`	Number of WAL files that have been successfully archived
`last_archived_wal`	`text`	Name of the last WAL file successfully archived
`last_archived_time`	`timestamp with time zone`	Time of the last successful archive operation
`failed_count`	`bigint`	Number of failed attempts for archiving WAL files
`last_failed_wal`	`text`	Name of the WAL file of the last failed archival operation
`last_failed_time`	`timestamp with time zone`	Time of the last failed archival operation
`stats_reset`	`timestamp with time zone`	Time at which these statistics were last reset

The `pg_stat_archiver` view will always have a single row, containing data about the archiver process of the cluster.

Table 27-4. `pg_stat_bgwriter` View

Column	Type	Description
`checkpoints_timed`	`bigint`	Number of scheduled checkpoints that have been performed
`checkpoints_req`	`bigint`	Number of requested checkpoints that have been performed
`checkpoint_write_time`	`double precision`	Total amount of time that has been spent in the portion of checkpoint processing where files are written to disk, in milliseconds
`checkpoint_sync_time`	`double precision`	Total amount of time that has been spent in the portion of checkpoint processing where files are synchronized to disk, in milliseconds
`buffers_checkpoint`	`bigint`	Number of buffers written during checkpoints
`buffers_clean`	`bigint`	Number of buffers written by the background writer
`maxwritten_clean`	`bigint`	Number of times the background writer stopped a cleaning scan because it had written too many buffers

Column	Type	Description
buffers_backend	bigint	Number of buffers written directly by a backend
buffers_backend_fsync	bigint	Number of times a backend had to execute its own fsync call (normally the background writer handles those even when the backend does its own write)
buffers_alloc	bigint	Number of buffers allocated
stats_reset	timestamp with time zone	Time at which these statistics were last reset

The pg_stat_bgwriter view will always have a single row, containing global data for the cluster.

Table 27-5. pg_stat_database View

Column	Type	Description
datid	oid	OID of a database
datname	name	Name of this database
numbackends	integer	Number of backends currently connected to this database. This is the only column in this view that returns a value reflecting current state; all other columns return the accumulated values since the last reset.
xact_commit	bigint	Number of transactions in this database that have been committed
xact_rollback	bigint	Number of transactions in this database that have been rolled back
blks_read	bigint	Number of disk blocks read in this database
blks_hit	bigint	Number of times disk blocks were found already in the buffer cache, so that a read was not necessary (this only includes hits in the PostgreSQL buffer cache, not the operating system's file system cache)
tup_returned	bigint	Number of rows returned by queries in this database
tup_fetched	bigint	Number of rows fetched by queries in this database
tup_inserted	bigint	Number of rows inserted by queries in this database

Column	Type	Description
tup_updated	bigint	Number of rows updated by queries in this database
tup_deleted	bigint	Number of rows deleted by queries in this database
conflicts	bigint	Number of queries canceled due to conflicts with recovery in this database. (Conflicts occur only on standby servers; see pg_stat_database_conflicts for details.)
temp_files	bigint	Number of temporary files created by queries in this database. All temporary files are counted, regardless of why the temporary file was created (e.g., sorting or hashing), and regardless of the log_temp_files setting.
temp_bytes	bigint	Total amount of data written to temporary files by queries in this database. All temporary files are counted, regardless of why the temporary file was created, and regardless of the log_temp_files setting.
deadlocks	bigint	Number of deadlocks detected in this database
blk_read_time	double precision	Time spent reading data file blocks by backends in this database, in milliseconds
blk_write_time	double precision	Time spent writing data file blocks by backends in this database, in milliseconds
stats_reset	timestamp with time zone	Time at which these statistics were last reset

The pg_stat_database view will contain one row for each database in the cluster, showing database-wide statistics.

Table 27-6. pg_stat_all_tables View

Column	Type	Description
relid	oid	OID of a table
schemaname	name	Name of the schema that this table is in
relname	name	Name of this table
seq_scan	bigint	Number of sequential scans initiated on this table

Column	Type	Description
seq_tup_read	bigint	Number of live rows fetched by sequential scans
idx_scan	bigint	Number of index scans initiated on this table
idx_tup_fetch	bigint	Number of live rows fetched by index scans
n_tup_ins	bigint	Number of rows inserted
n_tup_upd	bigint	Number of rows updated
n_tup_del	bigint	Number of rows deleted
n_tup_hot_upd	bigint	Number of rows HOT updated (i.e., with no separate index update required)
n_live_tup	bigint	Estimated number of live rows
n_dead_tup	bigint	Estimated number of dead rows
n_mod_since_analyze	bigint	Estimated number of rows modified since this table was last analyzed
last_vacuum	timestamp with time zone	Last time at which this table was manually vacuumed (not counting VACUUM FULL)
last_autovacuum	timestamp with time zone	Last time at which this table was vacuumed by the autovacuum daemon
last_analyze	timestamp with time zone	Last time at which this table was manually analyzed
last_autoanalyze	timestamp with time zone	Last time at which this table was analyzed by the autovacuum daemon
vacuum_count	bigint	Number of times this table has been manually vacuumed (not counting VACUUM FULL)
autovacuum_count	bigint	Number of times this table has been vacuumed by the autovacuum daemon
analyze_count	bigint	Number of times this table has been manually analyzed
autoanalyze_count	bigint	Number of times this table has been analyzed by the autovacuum daemon

The pg_stat_all_tables view will contain one row for each table in the current database (including TOAST tables), showing statistics about accesses to that specific table. The pg_stat_user_tables and pg_stat_sys_tables views contain the same information, but filtered to only show user and system tables respectively.

Table 27-7. pg_stat_all_indexes View

Column	Type	Description
relid	oid	OID of the table for this index
indexrelid	oid	OID of this index
schemaname	name	Name of the schema this index is in
relname	name	Name of the table for this index
indexrelname	name	Name of this index
idx_scan	bigint	Number of index scans initiated on this index
idx_tup_read	bigint	Number of index entries returned by scans on this index
idx_tup_fetch	bigint	Number of live table rows fetched by simple index scans using this index

The pg_stat_all_indexes view will contain one row for each index in the current database, showing statistics about accesses to that specific index. The pg_stat_user_indexes and pg_stat_sys_indexes views contain the same information, but filtered to only show user and system indexes respectively.

Indexes can be used via either simple index scans or "bitmap" index scans. In a bitmap scan the output of several indexes can be combined via AND or OR rules, so it is difficult to associate individual heap row fetches with specific indexes when a bitmap scan is used. Therefore, a bitmap scan increments the pg_stat_all_indexes.idx_tup_read count(s) for the index(es) it uses, and it increments the pg_stat_all_tables.idx_tup_fetch count for the table, but it does not affect pg_stat_all_indexes.idx_tup_fetch.

> **Note:** The idx_tup_read and idx_tup_fetch counts can be different even without any use of bitmap scans, because idx_tup_read counts index entries retrieved from the index while idx_tup_fetch counts live rows fetched from the table. The latter will be less if any dead or not-yet-committed rows are fetched using the index, or if any heap fetches are avoided by means of an index-only scan.

Table 27-8. pg_statio_all_tables View

Column	Type	Description
relid	oid	OID of a table
schemaname	name	Name of the schema that this table is in
relname	name	Name of this table
heap_blks_read	bigint	Number of disk blocks read from this table
heap_blks_hit	bigint	Number of buffer hits in this table
idx_blks_read	bigint	Number of disk blocks read from all indexes on this table

Column	Type	Description
idx_blks_hit	bigint	Number of buffer hits in all indexes on this table
toast_blks_read	bigint	Number of disk blocks read from this table's TOAST table (if any)
toast_blks_hit	bigint	Number of buffer hits in this table's TOAST table (if any)
tidx_blks_read	bigint	Number of disk blocks read from this table's TOAST table indexes (if any)
tidx_blks_hit	bigint	Number of buffer hits in this table's TOAST table indexes (if any)

The pg_statio_all_tables view will contain one row for each table in the current database (including TOAST tables), showing statistics about I/O on that specific table. The pg_statio_user_tables and pg_statio_sys_tables views contain the same information, but filtered to only show user and system tables respectively.

Table 27-9. pg_statio_all_indexes View

Column	Type	Description
relid	oid	OID of the table for this index
indexrelid	oid	OID of this index
schemaname	name	Name of the schema this index is in
relname	name	Name of the table for this index
indexrelname	name	Name of this index
idx_blks_read	bigint	Number of disk blocks read from this index
idx_blks_hit	bigint	Number of buffer hits in this index

The pg_statio_all_indexes view will contain one row for each index in the current database, showing statistics about I/O on that specific index. The pg_statio_user_indexes and pg_statio_sys_indexes views contain the same information, but filtered to only show user and system indexes respectively.

Table 27-10. pg_statio_all_sequences View

Column	Type	Description
relid	oid	OID of a sequence
schemaname	name	Name of the schema this sequence is in
relname	name	Name of this sequence
blks_read	bigint	Number of disk blocks read from this sequence

Column	Type	Description
blks_hit	bigint	Number of buffer hits in this sequence

The pg_statio_all_sequences view will contain one row for each sequence in the current database, showing statistics about I/O on that specific sequence.

Table 27-11. pg_stat_user_functions View

Column	Type	Description
funcid	oid	OID of a function
schemaname	name	Name of the schema this function is in
funcname	name	Name of this function
calls	bigint	Number of times this function has been called
total_time	double precision	Total time spent in this function and all other functions called by it, in milliseconds
self_time	double precision	Total time spent in this function itself, not including other functions called by it, in milliseconds

The pg_stat_user_functions view will contain one row for each tracked function, showing statistics about executions of that function. The track_functions parameter controls exactly which functions are tracked.

Table 27-12. pg_stat_replication View

Column	Type	Description
pid	integer	Process ID of a WAL sender process
usesysid	oid	OID of the user logged into this WAL sender process
usename	name	Name of the user logged into this WAL sender process
application_name	text	Name of the application that is connected to this WAL sender
client_addr	inet	IP address of the client connected to this WAL sender. If this field is null, it indicates that the client is connected via a Unix socket on the server machine.

Column	Type	Description
client_hostname	text	Host name of the connected client, as reported by a reverse DNS lookup of client_addr. This field will only be non-null for IP connections, and only when log_hostname is enabled.
client_port	integer	TCP port number that the client is using for communication with this WAL sender, or -1 if a Unix socket is used
backend_start	timestamp with time zone	Time when this process was started, i.e., when the client connected to this WAL sender
backend_xmin	xid	This standby's xmin horizon reported by hot_standby_feedback.
state	text	Current WAL sender state
sent_location	pg_lsn	Last transaction log position sent on this connection
write_location	pg_lsn	Last transaction log position written to disk by this standby server
flush_location	pg_lsn	Last transaction log position flushed to disk by this standby server
replay_location	pg_lsn	Last transaction log position replayed into the database on this standby server
sync_priority	integer	Priority of this standby server for being chosen as the synchronous standby
sync_state	text	Synchronous state of this standby server

The pg_stat_replication view will contain one row per WAL sender process, showing statistics about replication to that sender's connected standby server. Only directly connected standbys are listed; no information is available about downstream standby servers.

Table 27-13. pg_stat_database_conflicts View

Column	Type	Description
datid	oid	OID of a database
datname	name	Name of this database
confl_tablespace	bigint	Number of queries in this database that have been canceled due to dropped tablespaces

Column	Type	Description
confl_lock	bigint	Number of queries in this database that have been canceled due to lock timeouts
confl_snapshot	bigint	Number of queries in this database that have been canceled due to old snapshots
confl_bufferpin	bigint	Number of queries in this database that have been canceled due to pinned buffers
confl_deadlock	bigint	Number of queries in this database that have been canceled due to deadlocks

The pg_stat_database_conflicts view will contain one row per database, showing database-wide statistics about query cancels occurring due to conflicts with recovery on standby servers. This view will only contain information on standby servers, since conflicts do not occur on master servers.

27.2.3. Statistics Functions

Other ways of looking at the statistics can be set up by writing queries that use the same underlying statistics access functions used by the standard views shown above. For details such as the functions' names, consult the definitions of the standard views. (For example, in psql you could issue \d+ pg_stat_activity.) The access functions for per-database statistics take a database OID as an argument to identify which database to report on. The per-table and per-index functions take a table or index OID. The functions for per-function statistics take a function OID. Note that only tables, indexes, and functions in the current database can be seen with these functions.

Additional functions related to statistics collection are listed in Table 27-14.

Table 27-14. Additional Statistics Functions

Function	Return Type	Description
pg_backend_pid()	integer	Process ID of the server process handling the current session
pg_stat_get_activity(integer)	setof record	Returns a record of information about the backend with the specified PID, or one record for each active backend in the system if NULL is specified. The fields returned are a subset of those in the pg_stat_activity view.
pg_stat_clear_snapshot()	void	Discard the current statistics snapshot
pg_stat_reset()	void	Reset all statistics counters for the current database to zero (requires superuser privileges)

Function	Return Type	Description
pg_stat_reset_shared(text)	void	Reset some cluster-wide statistics counters to zero, depending on the argument (requires superuser privileges). Calling pg_stat_reset_shared('bgwriter') will zero all the counters shown in the pg_stat_bgwriter view. Calling pg_stat_reset_shared('archiver') will zero all the counters shown in the pg_stat_archiver view.
pg_stat_reset_single_table_counters(oid)	void	Reset statistics for a single table or index in the current database to zero (requires superuser privileges)
pg_stat_reset_single_function_counters(oid)	void	Reset statistics for a single function in the current database to zero (requires superuser privileges)

pg_stat_get_activity, the underlying function of the pg_stat_activity view, returns a set of records containing all the available information about each backend process. Sometimes it may be more convenient to obtain just a subset of this information. In such cases, an older set of per-backend statistics access functions can be used; these are shown in Table 27-15. These access functions use a backend ID number, which ranges from one to the number of currently active backends. The function pg_stat_get_backend_idset provides a convenient way to generate one row for each active backend for invoking these functions. For example, to show the PIDs and current queries of all backends:

```
SELECT pg_stat_get_backend_pid(s.backendid) AS pid,
       pg_stat_get_backend_activity(s.backendid) AS query
    FROM (SELECT pg_stat_get_backend_idset() AS backendid) AS s;
```

Table 27-15. Per-Backend Statistics Functions

Function	Return Type	Description
pg_stat_get_backend_idset()	setof integer	Set of currently active backend ID numbers (from 1 to the number of active backends)
pg_stat_get_backend_activity(integer)	text	Text of this backend's most recent query
pg_stat_get_backend_activity_start(integer)	timestamp with time zone	Time when the most recent query was started
pg_stat_get_backend_client_addr(integer)	inet	IP address of the client connected to this backend

Function	Return Type	Description
pg_stat_get_backend_client_port(integer)	integer	TCP port number that the client is using for communication
pg_stat_get_backend_dbid(integer)	oid	OID of the database this backend is connected to
pg_stat_get_backend_pid(integer)	integer	Process ID of this backend
pg_stat_get_backend_start(integer)	timestamp with time zone	Time when this process was started
pg_stat_get_backend_userid(integer)	oid	OID of the user logged into this backend
pg_stat_get_backend_waiting(integer)	boolean	True if this backend is currently waiting on a lock
pg_stat_get_backend_xact_start(integer)	timestamp with time zone	Time when the current transaction was started

27.3. Viewing Locks

Another useful tool for monitoring database activity is the pg_locks system table. It allows the database administrator to view information about the outstanding locks in the lock manager. For example, this capability can be used to:

- View all the locks currently outstanding, all the locks on relations in a particular database, all the locks on a particular relation, or all the locks held by a particular PostgreSQL session.
- Determine the relation in the current database with the most ungranted locks (which might be a source of contention among database clients).
- Determine the effect of lock contention on overall database performance, as well as the extent to which contention varies with overall database traffic.

Details of the pg_locks view appear in Section 48.60. For more information on locking and managing concurrency with PostgreSQL, refer to Chapter 13.

27.4. Dynamic Tracing

PostgreSQL provides facilities to support dynamic tracing of the database server. This allows an external utility to be called at specific points in the code and thereby trace execution.

A number of probes or trace points are already inserted into the source code. These probes are intended to be used by database developers and administrators. By default the probes are not compiled into PostgreSQL; the user needs to explicitly tell the configure script to make the probes available.

Currently, the DTrace[1] utility is supported, which, at the time of this writing, is available on Solaris, OS X, FreeBSD, NetBSD, and Oracle Linux. The SystemTap[2] project for Linux provides a DTrace

1. https://en.wikipedia.org/wiki/DTrace
2. http://sourceware.org/systemtap/

equivalent and can also be used. Supporting other dynamic tracing utilities is theoretically possible by changing the definitions for the macros in `src/include/utils/probes.h`.

27.4.1. Compiling for Dynamic Tracing

By default, probes are not available, so you will need to explicitly tell the configure script to make the probes available in PostgreSQL. To include DTrace support specify `--enable-dtrace` to configure. See Section 15.4 for further information.

27.4.2. Built-in Probes

A number of standard probes are provided in the source code, as shown in Table 27-16; Table 27-17 shows the types used in the probes. More probes can certainly be added to enhance PostgreSQL's observability.

Table 27-16. Built-in DTrace Probes

Name	Parameters	Description
transaction-start	(LocalTransactionId)	Probe that fires at the start of a new transaction. arg0 is the transaction ID.
transaction-commit	(LocalTransactionId)	Probe that fires when a transaction completes successfully. arg0 is the transaction ID.
transaction-abort	(LocalTransactionId)	Probe that fires when a transaction completes unsuccessfully. arg0 is the transaction ID.
query-start	(const char *)	Probe that fires when the processing of a query is started. arg0 is the query string.
query-done	(const char *)	Probe that fires when the processing of a query is complete. arg0 is the query string.
query-parse-start	(const char *)	Probe that fires when the parsing of a query is started. arg0 is the query string.
query-parse-done	(const char *)	Probe that fires when the parsing of a query is complete. arg0 is the query string.
query-rewrite-start	(const char *)	Probe that fires when the rewriting of a query is started. arg0 is the query string.

Name	Parameters	Description
query-rewrite-done	(const char *)	Probe that fires when the rewriting of a query is complete. arg0 is the query string.
query-plan-start	()	Probe that fires when the planning of a query is started.
query-plan-done	()	Probe that fires when the planning of a query is complete.
query-execute-start	()	Probe that fires when the execution of a query is started.
query-execute-done	()	Probe that fires when the execution of a query is complete.
statement-status	(const char *)	Probe that fires anytime the server process updates its `pg_stat_activity.status`. arg0 is the new status string.
checkpoint-start	(int)	Probe that fires when a checkpoint is started. arg0 holds the bitwise flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
checkpoint-done	(int, int, int, int, int)	Probe that fires when a checkpoint is complete. (The probes listed next fire in sequence during checkpoint processing.) arg0 is the number of buffers written. arg1 is the total number of buffers. arg2, arg3 and arg4 contain the number of xlog file(s) added, removed and recycled respectively.
clog-checkpoint-start	(bool)	Probe that fires when the CLOG portion of a checkpoint is started. arg0 is true for normal checkpoint, false for shutdown checkpoint.
clog-checkpoint-done	(bool)	Probe that fires when the CLOG portion of a checkpoint is complete. arg0 has the same meaning as for clog-checkpoint-start.

Name	Parameters	Description
subtrans-checkpoint-start	(bool)	Probe that fires when the SUBTRANS portion of a checkpoint is started. arg0 is true for normal checkpoint, false for shutdown checkpoint.
subtrans-checkpoint-done	(bool)	Probe that fires when the SUBTRANS portion of a checkpoint is complete. arg0 has the same meaning as for subtrans-checkpoint-start.
multixact-checkpoint-start	(bool)	Probe that fires when the MultiXact portion of a checkpoint is started. arg0 is true for normal checkpoint, false for shutdown checkpoint.
multixact-checkpoint-done	(bool)	Probe that fires when the MultiXact portion of a checkpoint is complete. arg0 has the same meaning as for multixact-checkpoint-start.
buffer-checkpoint-start	(int)	Probe that fires when the buffer-writing portion of a checkpoint is started. arg0 holds the bitwise flags used to distinguish different checkpoint types, such as shutdown, immediate or force.
buffer-sync-start	(int, int)	Probe that fires when we begin to write dirty buffers during checkpoint (after identifying which buffers must be written). arg0 is the total number of buffers. arg1 is the number that are currently dirty and need to be written.
buffer-sync-written	(int)	Probe that fires after each buffer is written during checkpoint. arg0 is the ID number of the buffer.

Name	Parameters	Description
buffer-sync-done	(int, int, int)	Probe that fires when all dirty buffers have been written. arg0 is the total number of buffers. arg1 is the number of buffers actually written by the checkpoint process. arg2 is the number that were expected to be written (arg1 of buffer-sync-start); any difference reflects other processes flushing buffers during the checkpoint.
buffer-checkpoint-sync-start	()	Probe that fires after dirty buffers have been written to the kernel, and before starting to issue fsync requests.
buffer-checkpoint-done	()	Probe that fires when syncing of buffers to disk is complete.
twophase-checkpoint-start	()	Probe that fires when the two-phase portion of a checkpoint is started.
twophase-checkpoint-done	()	Probe that fires when the two-phase portion of a checkpoint is complete.
buffer-read-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, bool)	Probe that fires when a buffer read is started. arg0 and arg1 contain the fork and block numbers of the page (but arg1 will be -1 if this is a relation extension request). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read.

Name	Parameters	Description
buffer-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, bool, bool)	Probe that fires when a buffer read is complete. arg0 and arg1 contain the fork and block numbers of the page (if this is a relation extension request, arg1 now contains the block number of the newly added block). arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is true for a relation extension request, false for normal read. arg7 is true if the buffer was found in the pool, false if not.
buffer-flush-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires before issuing any write request for a shared buffer. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.
buffer-flush-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a write request is complete. (Note that this just reflects the time to pass the data to the kernel; it's typically not actually been written to disk yet.) The arguments are the same as for buffer-flush-start.
buffer-write-dirty-start	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a server process begins to write a dirty buffer. (If this happens often, it implies that shared_buffers is too small or the bgwriter control parameters need adjustment.) arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation.

Name	Parameters	Description
buffer-write-dirty-done	(ForkNumber, BlockNumber, Oid, Oid, Oid)	Probe that fires when a dirty-buffer write is complete. The arguments are the same as for buffer-write-dirty-start.
wal-buffer-write-dirty-start	()	Probe that fires when a server process begins to write a dirty WAL buffer because no more WAL buffer space is available. (If this happens often, it implies that wal_buffers is too small.)
wal-buffer-write-dirty-done	()	Probe that fires when a dirty WAL buffer write is complete.
xlog-insert	(unsigned char, unsigned char)	Probe that fires when a WAL record is inserted. arg0 is the resource manager (rmid) for the record. arg1 contains the info flags.
xlog-switch	()	Probe that fires when a WAL segment switch is requested.
smgr-md-read-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to read a block from a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.
smgr-md-read-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block read is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually read, while arg7 is the number requested (if these are different it indicates trouble).

Name	Parameters	Description
smgr-md-write-start	(ForkNumber, BlockNumber, Oid, Oid, Oid, int)	Probe that fires when beginning to write a block to a relation. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer.
smgr-md-write-done	(ForkNumber, BlockNumber, Oid, Oid, Oid, int, int, int)	Probe that fires when a block write is complete. arg0 and arg1 contain the fork and block numbers of the page. arg2, arg3, and arg4 contain the tablespace, database, and relation OIDs identifying the relation. arg5 is the ID of the backend which created the temporary relation for a local buffer, or InvalidBackendId (-1) for a shared buffer. arg6 is the number of bytes actually written, while arg7 is the number requested (if these are different it indicates trouble).
sort-start	(int, bool, int, int, bool)	Probe that fires when a sort operation is started. arg0 indicates heap, index or datum sort. arg1 is true for unique-value enforcement. arg2 is the number of key columns. arg3 is the number of kilobytes of work memory allowed. arg4 is true if random access to the sort result is required.
sort-done	(bool, long)	Probe that fires when a sort is complete. arg0 is true for external sort, false for internal sort. arg1 is the number of disk blocks used for an external sort, or kilobytes of memory used for an internal sort.

Name	Parameters	Description
lwlock-acquire	(char *, int, LWLockMode)	Probe that fires when an LWLock has been acquired. arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche. arg2 is the requested lock mode, either exclusive or shared.
lwlock-release	(char *, int)	Probe that fires when an LWLock has been released (but note that any released waiters have not yet been awakened). arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche.
lwlock-wait-start	(char *, int, LWLockMode)	Probe that fires when an LWLock was not immediately available and a server process has begun to wait for the lock to become available. arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche. arg2 is the requested lock mode, either exclusive or shared.
lwlock-wait-done	(char *, int, LWLockMode)	Probe that fires when a server process has been released from its wait for an LWLock (it does not actually have the lock yet). arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche. arg2 is the requested lock mode, either exclusive or shared.
lwlock-condacquire	(char *, int, LWLockMode)	Probe that fires when an LWLock was successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche. arg2 is the requested lock mode, either exclusive or shared.

Name	Parameters	Description
lwlock-condacquire-fail	(char *, int, LWLockMode)	Probe that fires when an LWLock was not successfully acquired when the caller specified no waiting. arg0 is the LWLock's tranche. arg1 is the LWLock's offset within its tranche. arg2 is the requested lock mode, either exclusive or shared.
lock-wait-start	(unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has begun to wait because the lock is not available. arg0 through arg3 are the tag fields identifying the object being locked. arg4 indicates the type of object being locked. arg5 indicates the lock type being requested.
lock-wait-done	(unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, LOCKMODE)	Probe that fires when a request for a heavyweight lock (lmgr lock) has finished waiting (i.e., has acquired the lock). The arguments are the same as for lock-wait-start.
deadlock-found	()	Probe that fires when a deadlock is found by the deadlock detector.

Table 27-17. Defined Types Used in Probe Parameters

Type	Definition
LocalTransactionId	unsigned int
LWLockMode	int
LOCKMODE	int
BlockNumber	unsigned int
Oid	unsigned int
ForkNumber	int
bool	char

27.4.3. Using Probes

The example below shows a DTrace script for analyzing transaction counts in the system, as an alternative to snapshotting `pg_stat_database` before and after a performance test:

```
#!/usr/sbin/dtrace -qs
```

```
postgresql$1:::transaction-start
{
      @start["Start"] = count();
      self->ts  = timestamp;
}

postgresql$1:::transaction-abort
{
      @abort["Abort"] = count();
}

postgresql$1:::transaction-commit
/self->ts/
{
      @commit["Commit"] = count();
      @time["Total time (ns)"] = sum(timestamp - self->ts);
      self->ts=0;
}
```

When executed, the example D script gives output such as:

```
# ./txn_count.d `pgrep -n postgres` or ./txn_count.d <PID>
^C

Start                                          71
Commit                                         70
Total time (ns)                        2312105013
```

> **Note:** SystemTap uses a different notation for trace scripts than DTrace does, even though the underlying trace points are compatible. One point worth noting is that at this writing, SystemTap scripts must reference probe names using double underscores in place of hyphens. This is expected to be fixed in future SystemTap releases.

You should remember that DTrace scripts need to be carefully written and debugged, otherwise the trace information collected might be meaningless. In most cases where problems are found it is the instrumentation that is at fault, not the underlying system. When discussing information found using dynamic tracing, be sure to enclose the script used to allow that too to be checked and discussed.

More example scripts can be found in the PgFoundry dtrace project[3].

27.4.4. Defining New Probes

New probes can be defined within the code wherever the developer desires, though this will require a recompilation. Below are the steps for inserting new probes:

1. Decide on probe names and data to be made available through the probes
2. Add the probe definitions to `src/backend/utils/probes.d`
3. Include `pg_trace.h` if it is not already present in the module(s) containing the probe points, and insert `TRACE_POSTGRESQL` probe macros at the desired locations in the source code

3. http://pgfoundry.org/projects/dtrace/

4. Recompile and verify that the new probes are available

Example: Here is an example of how you would add a probe to trace all new transactions by transaction ID.

1. Decide that the probe will be named `transaction-start` and requires a parameter of type LocalTransactionId
2. Add the probe definition to `src/backend/utils/probes.d`:

   ```
   probe transaction__start(LocalTransactionId);
   ```

   Note the use of the double underline in the probe name. In a DTrace script using the probe, the double underline needs to be replaced with a hyphen, so `transaction-start` is the name to document for users.
3. At compile time, `transaction__start` is converted to a macro called `TRACE_POSTGRESQL_TRANSACTION_START` (notice the underscores are single here), which is available by including `pg_trace.h`. Add the macro call to the appropriate location in the source code. In this case, it looks like the following:

   ```
   TRACE_POSTGRESQL_TRANSACTION_START(vxid.localTransactionId);
   ```
4. After recompiling and running the new binary, check that your newly added probe is available by executing the following DTrace command. You should see similar output:

   ```
   # dtrace -ln transaction-start
      ID    PROVIDER          MODULE           FUNCTION NAME
   18705 postgresql49878     postgres     StartTransactionCommand transaction-start
   18755 postgresql49877     postgres     StartTransactionCommand transaction-start
   18805 postgresql49876     postgres     StartTransactionCommand transaction-start
   18855 postgresql49875     postgres     StartTransactionCommand transaction-start
   18986 postgresql49873     postgres     StartTransactionCommand transaction-start
   ```

There are a few things to be careful about when adding trace macros to the C code:

- You should take care that the data types specified for a probe's parameters match the data types of the variables used in the macro. Otherwise, you will get compilation errors.
- On most platforms, if PostgreSQL is built with `--enable-dtrace`, the arguments to a trace macro will be evaluated whenever control passes through the macro, *even if no tracing is being done*. This is usually not worth worrying about if you are just reporting the values of a few local variables. But beware of putting expensive function calls into the arguments. If you need to do that, consider protecting the macro with a check to see if the trace is actually enabled:

  ```
  if (TRACE_POSTGRESQL_TRANSACTION_START_ENABLED())
      TRACE_POSTGRESQL_TRANSACTION_START(some_function(...));
  ```

  Each trace macro has a corresponding `ENABLED` macro.

Chapter 28. Monitoring Disk Usage

This chapter discusses how to monitor the disk usage of a PostgreSQL database system.

28.1. Determining Disk Usage

Each table has a primary heap disk file where most of the data is stored. If the table has any columns with potentially-wide values, there also might be a TOAST file associated with the table, which is used to store values too wide to fit comfortably in the main table (see Section 59.2). There will be one valid index on the TOAST table, if present. There also might be indexes associated with the base table. Each table and index is stored in a separate disk file — possibly more than one file, if the file would exceed one gigabyte. Naming conventions for these files are described in Section 59.1.

You can monitor disk space in three ways: using the SQL functions listed in Table 9-70, using the oid2name module, or using manual inspection of the system catalogs. The SQL functions are the easiest to use and are generally recommended. The remainder of this section shows how to do it by inspection of the system catalogs.

Using psql on a recently vacuumed or analyzed database, you can issue queries to see the disk usage of any table:

```
SELECT pg_relation_filepath(oid), relpages FROM pg_class WHERE relname = 'customer';

 pg_relation_filepath | relpages
----------------------+----------
 base/16384/16806     |       60
(1 row)
```

Each page is typically 8 kilobytes. (Remember, `relpages` is only updated by `VACUUM`, `ANALYZE`, and a few DDL commands such as `CREATE INDEX`.) The file path name is of interest if you want to examine the table's disk file directly.

To show the space used by TOAST tables, use a query like the following:

```
SELECT relname, relpages
FROM pg_class,
     (SELECT reltoastrelid
      FROM pg_class
      WHERE relname = 'customer') AS ss
WHERE oid = ss.reltoastrelid OR
      oid = (SELECT indexrelid
             FROM pg_index
             WHERE indrelid = ss.reltoastrelid)
ORDER BY relname;

       relname        | relpages
----------------------+----------
 pg_toast_16806       |        0
 pg_toast_16806_index |        1
```

You can easily display index sizes, too:

```
SELECT c2.relname, c2.relpages
FROM pg_class c, pg_class c2, pg_index i
```

```
WHERE c.relname = 'customer' AND
      c.oid = i.indrelid AND
      c2.oid = i.indexrelid
ORDER BY c2.relname;

       relname        | relpages
----------------------+----------
 customer_id_indexdex |       26
```

It is easy to find your largest tables and indexes using this information:

```
SELECT relname, relpages
FROM pg_class
ORDER BY relpages DESC;

       relname        | relpages
----------------------+----------
 bigtable             |     3290
 customer             |     3144
```

28.2. Disk Full Failure

The most important disk monitoring task of a database administrator is to make sure the disk doesn't become full. A filled data disk will not result in data corruption, but it might prevent useful activity from occurring. If the disk holding the WAL files grows full, database server panic and consequent shutdown might occur.

If you cannot free up additional space on the disk by deleting other things, you can move some of the database files to other file systems by making use of tablespaces. See Section 21.6 for more information about that.

> **Tip:** Some file systems perform badly when they are almost full, so do not wait until the disk is completely full to take action.

If your system supports per-user disk quotas, then the database will naturally be subject to whatever quota is placed on the user the server runs as. Exceeding the quota will have the same bad effects as running out of disk space entirely.

Chapter 29. Reliability and the Write-Ahead Log

This chapter explains how the Write-Ahead Log is used to obtain efficient, reliable operation.

29.1. Reliability

Reliability is an important property of any serious database system, and PostgreSQL does everything possible to guarantee reliable operation. One aspect of reliable operation is that all data recorded by a committed transaction should be stored in a nonvolatile area that is safe from power loss, operating system failure, and hardware failure (except failure of the nonvolatile area itself, of course). Successfully writing the data to the computer's permanent storage (disk drive or equivalent) ordinarily meets this requirement. In fact, even if a computer is fatally damaged, if the disk drives survive they can be moved to another computer with similar hardware and all committed transactions will remain intact.

While forcing data to the disk platters periodically might seem like a simple operation, it is not. Because disk drives are dramatically slower than main memory and CPUs, several layers of caching exist between the computer's main memory and the disk platters. First, there is the operating system's buffer cache, which caches frequently requested disk blocks and combines disk writes. Fortunately, all operating systems give applications a way to force writes from the buffer cache to disk, and PostgreSQL uses those features. (See the wal_sync_method parameter to adjust how this is done.)

Next, there might be a cache in the disk drive controller; this is particularly common on RAID controller cards. Some of these caches are *write-through*, meaning writes are sent to the drive as soon as they arrive. Others are *write-back*, meaning data is sent to the drive at some later time. Such caches can be a reliability hazard because the memory in the disk controller cache is volatile, and will lose its contents in a power failure. Better controller cards have *battery-backup units* (BBUs), meaning the card has a battery that maintains power to the cache in case of system power loss. After power is restored the data will be written to the disk drives.

And finally, most disk drives have caches. Some are write-through while some are write-back, and the same concerns about data loss exist for write-back drive caches as for disk controller caches. Consumer-grade IDE and SATA drives are particularly likely to have write-back caches that will not survive a power failure. Many solid-state drives (SSD) also have volatile write-back caches.

These caches can typically be disabled; however, the method for doing this varies by operating system and drive type:

- On Linux, IDE and SATA drives can be queried using `hdparm -I`; write caching is enabled if there is a `*` next to `Write cache`. `hdparm -W 0` can be used to turn off write caching. SCSI drives can be queried using sdparm[1]. Use `sdparm --get=WCE` to check whether the write cache is enabled and `sdparm --clear=WCE` to disable it.
- On FreeBSD, IDE drives can be queried using `atacontrol` and write caching turned off using `hw.ata.wc=0` in `/boot/loader.conf`; SCSI drives can be queried using `camcontrol identify`, and the write cache both queried and changed using `sdparm` when available.
- On Solaris, the disk write cache is controlled by `format -e`. (The Solaris ZFS file system is safe with disk write-cache enabled because it issues its own disk cache flush commands.)

1. http://sg.danny.cz/sg/sdparm.html

- On Windows, if `wal_sync_method` is `open_datasync` (the default), write caching can be disabled by unchecking `My Computer\Open\`*`disk drive`*`\Properties\Hardware\Properties\Policies\Enable write caching on the disk`. Alternatively, set `wal_sync_method` to `fsync` or `fsync_writethrough`, which prevent write caching.
- On OS X, write caching can be prevented by setting `wal_sync_method` to `fsync_writethrough`.

Recent SATA drives (those following ATAPI-6 or later) offer a drive cache flush command (`FLUSH CACHE EXT`), while SCSI drives have long supported a similar command `SYNCHRONIZE CACHE`. These commands are not directly accessible to PostgreSQL, but some file systems (e.g., ZFS, ext4) can use them to flush data to the platters on write-back-enabled drives. Unfortunately, such file systems behave suboptimally when combined with battery-backup unit (BBU) disk controllers. In such setups, the synchronize command forces all data from the controller cache to the disks, eliminating much of the benefit of the BBU. You can run the pg_test_fsync program to see if you are affected. If you are affected, the performance benefits of the BBU can be regained by turning off write barriers in the file system or reconfiguring the disk controller, if that is an option. If write barriers are turned off, make sure the battery remains functional; a faulty battery can potentially lead to data loss. Hopefully file system and disk controller designers will eventually address this suboptimal behavior.

When the operating system sends a write request to the storage hardware, there is little it can do to make sure the data has arrived at a truly non-volatile storage area. Rather, it is the administrator's responsibility to make certain that all storage components ensure integrity for both data and file-system metadata. Avoid disk controllers that have non-battery-backed write caches. At the drive level, disable write-back caching if the drive cannot guarantee the data will be written before shutdown. If you use SSDs, be aware that many of these do not honor cache flush commands by default. You can test for reliable I/O subsystem behavior using `diskchecker.pl`[2].

Another risk of data loss is posed by the disk platter write operations themselves. Disk platters are divided into sectors, commonly 512 bytes each. Every physical read or write operation processes a whole sector. When a write request arrives at the drive, it might be for some multiple of 512 bytes (PostgreSQL typically writes 8192 bytes, or 16 sectors, at a time), and the process of writing could fail due to power loss at any time, meaning some of the 512-byte sectors were written while others were not. To guard against such failures, PostgreSQL periodically writes full page images to permanent WAL storage *before* modifying the actual page on disk. By doing this, during crash recovery PostgreSQL can restore partially-written pages from WAL. If you have file-system software that prevents partial page writes (e.g., ZFS), you can turn off this page imaging by turning off the full_page_writes parameter. Battery-Backed Unit (BBU) disk controllers do not prevent partial page writes unless they guarantee that data is written to the BBU as full (8kB) pages.

PostgreSQL also protects against some kinds of data corruption on storage devices that may occur because of hardware errors or media failure over time, such as reading/writing garbage data.

- Each individual record in a WAL file is protected by a CRC-32 (32-bit) check that allows us to tell if record contents are correct. The CRC value is set when we write each WAL record and checked during crash recovery, archive recovery and replication.
- Data pages are not currently checksummed by default, though full page images recorded in WAL records will be protected; see initdb for details about enabling data page checksums.
- Internal data structures such as `pg_clog`, `pg_subtrans`, `pg_multixact`, `pg_serial`, `pg_notify`, `pg_stat`, `pg_snapshots` are not directly checksummed, nor are pages protected by full page writes. However, where such data structures are persistent, WAL records are written

2. http://brad.livejournal.com/2116715.html

that allow recent changes to be accurately rebuilt at crash recovery and those WAL records are protected as discussed above.

- Individual state files in `pg_twophase` are protected by CRC-32.
- Temporary data files used in larger SQL queries for sorts, materializations and intermediate results are not currently checksummed, nor will WAL records be written for changes to those files.

PostgreSQL does not protect against correctable memory errors and it is assumed you will operate using RAM that uses industry standard Error Correcting Codes (ECC) or better protection.

29.2. Write-Ahead Logging (WAL)

Write-Ahead Logging (WAL) is a standard method for ensuring data integrity. A detailed description can be found in most (if not all) books about transaction processing. Briefly, WAL's central concept is that changes to data files (where tables and indexes reside) must be written only after those changes have been logged, that is, after log records describing the changes have been flushed to permanent storage. If we follow this procedure, we do not need to flush data pages to disk on every transaction commit, because we know that in the event of a crash we will be able to recover the database using the log: any changes that have not been applied to the data pages can be redone from the log records. (This is roll-forward recovery, also known as REDO.)

> **Tip:** Because WAL restores database file contents after a crash, journaled file systems are not necessary for reliable storage of the data files or WAL files. In fact, journaling overhead can reduce performance, especially if journaling causes file system *data* to be flushed to disk. Fortunately, data flushing during journaling can often be disabled with a file system mount option, e.g. `data=writeback` on a Linux ext3 file system. Journaled file systems do improve boot speed after a crash.

Using WAL results in a significantly reduced number of disk writes, because only the log file needs to be flushed to disk to guarantee that a transaction is committed, rather than every data file changed by the transaction. The log file is written sequentially, and so the cost of syncing the log is much less than the cost of flushing the data pages. This is especially true for servers handling many small transactions touching different parts of the data store. Furthermore, when the server is processing many small concurrent transactions, one `fsync` of the log file may suffice to commit many transactions.

WAL also makes it possible to support on-line backup and point-in-time recovery, as described in Section 24.3. By archiving the WAL data we can support reverting to any time instant covered by the available WAL data: we simply install a prior physical backup of the database, and replay the WAL log just as far as the desired time. What's more, the physical backup doesn't have to be an instantaneous snapshot of the database state — if it is made over some period of time, then replaying the WAL log for that period will fix any internal inconsistencies.

29.3. Asynchronous Commit

Asynchronous commit is an option that allows transactions to complete more quickly, at the cost that the most recent transactions may be lost if the database should crash. In many applications this is an acceptable trade-off.

As described in the previous section, transaction commit is normally *synchronous*: the server waits for the transaction's WAL records to be flushed to permanent storage before returning a success indication to the client. The client is therefore guaranteed that a transaction reported to be committed will be preserved, even in the event of a server crash immediately after. However, for short transactions this delay is a major component of the total transaction time. Selecting asynchronous commit mode means that the server returns success as soon as the transaction is logically completed, before the WAL records it generated have actually made their way to disk. This can provide a significant boost in throughput for small transactions.

Asynchronous commit introduces the risk of data loss. There is a short time window between the report of transaction completion to the client and the time that the transaction is truly committed (that is, it is guaranteed not to be lost if the server crashes). Thus asynchronous commit should not be used if the client will take external actions relying on the assumption that the transaction will be remembered. As an example, a bank would certainly not use asynchronous commit for a transaction recording an ATM's dispensing of cash. But in many scenarios, such as event logging, there is no need for a strong guarantee of this kind.

The risk that is taken by using asynchronous commit is of data loss, not data corruption. If the database should crash, it will recover by replaying WAL up to the last record that was flushed. The database will therefore be restored to a self-consistent state, but any transactions that were not yet flushed to disk will not be reflected in that state. The net effect is therefore loss of the last few transactions. Because the transactions are replayed in commit order, no inconsistency can be introduced — for example, if transaction B made changes relying on the effects of a previous transaction A, it is not possible for A's effects to be lost while B's effects are preserved.

The user can select the commit mode of each transaction, so that it is possible to have both synchronous and asynchronous commit transactions running concurrently. This allows flexible trade-offs between performance and certainty of transaction durability. The commit mode is controlled by the user-settable parameter synchronous_commit, which can be changed in any of the ways that a configuration parameter can be set. The mode used for any one transaction depends on the value of `synchronous_commit` when transaction commit begins.

Certain utility commands, for instance `DROP TABLE`, are forced to commit synchronously regardless of the setting of `synchronous_commit`. This is to ensure consistency between the server's file system and the logical state of the database. The commands supporting two-phase commit, such as `PREPARE TRANSACTION`, are also always synchronous.

If the database crashes during the risk window between an asynchronous commit and the writing of the transaction's WAL records, then changes made during that transaction *will* be lost. The duration of the risk window is limited because a background process (the "WAL writer") flushes unwritten WAL records to disk every wal_writer_delay milliseconds. The actual maximum duration of the risk window is three times `wal_writer_delay` because the WAL writer is designed to favor writing whole pages at a time during busy periods.

Caution

An immediate-mode shutdown is equivalent to a server crash, and will therefore cause loss of any unflushed asynchronous commits.

Asynchronous commit provides behavior different from setting fsync = off. `fsync` is a server-wide setting that will alter the behavior of all transactions. It disables all logic within PostgreSQL that attempts to synchronize writes to different portions of the database, and therefore a system crash (that is, a hardware or operating system crash, not a failure of PostgreSQL itself) could result in arbitrarily bad corruption of the database state. In many scenarios, asynchronous commit provides most of the

performance improvement that could be obtained by turning off `fsync`, but without the risk of data corruption.

commit_delay also sounds very similar to asynchronous commit, but it is actually a synchronous commit method (in fact, `commit_delay` is ignored during an asynchronous commit). `commit_delay` causes a delay just before a transaction flushes WAL to disk, in the hope that a single flush executed by one such transaction can also serve other transactions committing at about the same time. The setting can be thought of as a way of increasing the time window in which transactions can join a group about to participate in a single flush, to amortize the cost of the flush among multiple transactions.

29.4. WAL Configuration

There are several WAL-related configuration parameters that affect database performance. This section explains their use. Consult Chapter 18 for general information about setting server configuration parameters.

Checkpoints are points in the sequence of transactions at which it is guaranteed that the heap and index data files have been updated with all information written before that checkpoint. At checkpoint time, all dirty data pages are flushed to disk and a special checkpoint record is written to the log file. (The change records were previously flushed to the WAL files.) In the event of a crash, the crash recovery procedure looks at the latest checkpoint record to determine the point in the log (known as the redo record) from which it should start the REDO operation. Any changes made to data files before that point are guaranteed to be already on disk. Hence, after a checkpoint, log segments preceding the one containing the redo record are no longer needed and can be recycled or removed. (When WAL archiving is being done, the log segments must be archived before being recycled or removed.)

The checkpoint requirement of flushing all dirty data pages to disk can cause a significant I/O load. For this reason, checkpoint activity is throttled so that I/O begins at checkpoint start and completes before the next checkpoint is due to start; this minimizes performance degradation during checkpoints.

The server's checkpointer process automatically performs a checkpoint every so often. A checkpoint is begun every checkpoint_segments log segments, or every checkpoint_timeout seconds, whichever comes first. The default settings are 3 segments and 300 seconds (5 minutes), respectively. If no WAL has been written since the previous checkpoint, new checkpoints will be skipped even if `checkpoint_timeout` has passed. (If WAL archiving is being used and you want to put a lower limit on how often files are archived in order to bound potential data loss, you should adjust the archive_timeout parameter rather than the checkpoint parameters.) It is also possible to force a checkpoint by using the SQL command `CHECKPOINT`.

Reducing `checkpoint_segments` and/or `checkpoint_timeout` causes checkpoints to occur more often. This allows faster after-crash recovery, since less work will need to be redone. However, one must balance this against the increased cost of flushing dirty data pages more often. If full_page_writes is set (as is the default), there is another factor to consider. To ensure data page consistency, the first modification of a data page after each checkpoint results in logging the entire page content. In that case, a smaller checkpoint interval increases the volume of output to the WAL log, partially negating the goal of using a smaller interval, and in any case causing more disk I/O.

Checkpoints are fairly expensive, first because they require writing out all currently dirty buffers, and second because they result in extra subsequent WAL traffic as discussed above. It is therefore wise to set the checkpointing parameters high enough so that checkpoints don't happen too often. As a simple sanity check on your checkpointing parameters, you can set the checkpoint_warning parameter. If checkpoints happen closer together than `checkpoint_warning` seconds, a message will be output to the server log recommending increasing `checkpoint_segments`. Occasional appearance of such a message is not cause for alarm, but if it appears often then the checkpoint control parameters should

be increased. Bulk operations such as large COPY transfers might cause a number of such warnings to appear if you have not set checkpoint_segments high enough.

To avoid flooding the I/O system with a burst of page writes, writing dirty buffers during a checkpoint is spread over a period of time. That period is controlled by checkpoint_completion_target, which is given as a fraction of the checkpoint interval. The I/O rate is adjusted so that the checkpoint finishes when the given fraction of checkpoint_segments WAL segments have been consumed since checkpoint start, or the given fraction of checkpoint_timeout seconds have elapsed, whichever is sooner. With the default value of 0.5, PostgreSQL can be expected to complete each checkpoint in about half the time before the next checkpoint starts. On a system that's very close to maximum I/O throughput during normal operation, you might want to increase checkpoint_completion_target to reduce the I/O load from checkpoints. The disadvantage of this is that prolonging checkpoints affects recovery time, because more WAL segments will need to be kept around for possible use in recovery. Although checkpoint_completion_target can be set as high as 1.0, it is best to keep it less than that (perhaps 0.9 at most) since checkpoints include some other activities besides writing dirty buffers. A setting of 1.0 is quite likely to result in checkpoints not being completed on time, which would result in performance loss due to unexpected variation in the number of WAL segments needed.

There will always be at least one WAL segment file, and will normally not be more than (2 + checkpoint_completion_target) * checkpoint_segments + 1 or checkpoint_segments + wal_keep_segments + 1 files. Each segment file is normally 16 MB (though this size can be altered when building the server). You can use this to estimate space requirements for WAL. Ordinarily, when old log segment files are no longer needed, they are recycled (that is, renamed to become future segments in the numbered sequence). If, due to a short-term peak of log output rate, there are more than 3 * checkpoint_segments + 1 segment files, the unneeded segment files will be deleted instead of recycled until the system gets back under this limit.

In archive recovery or standby mode, the server periodically performs *restartpoints*, which are similar to checkpoints in normal operation: the server forces all its state to disk, updates the pg_control file to indicate that the already-processed WAL data need not be scanned again, and then recycles any old log segment files in the pg_xlog directory. Restartpoints can't be performed more frequently than checkpoints in the master because restartpoints can only be performed at checkpoint records. A restartpoint is triggered when a checkpoint record is reached if at least checkpoint_timeout seconds have passed since the last restartpoint. In standby mode, a restartpoint is also triggered if at least checkpoint_segments log segments have been replayed since the last restartpoint.

There are two commonly used internal WAL functions: XLogInsert and XLogFlush. XLogInsert is used to place a new record into the WAL buffers in shared memory. If there is no space for the new record, XLogInsert will have to write (move to kernel cache) a few filled WAL buffers. This is undesirable because XLogInsert is used on every database low level modification (for example, row insertion) at a time when an exclusive lock is held on affected data pages, so the operation needs to be as fast as possible. What is worse, writing WAL buffers might also force the creation of a new log segment, which takes even more time. Normally, WAL buffers should be written and flushed by an XLogFlush request, which is made, for the most part, at transaction commit time to ensure that transaction records are flushed to permanent storage. On systems with high log output, XLogFlush requests might not occur often enough to prevent XLogInsert from having to do writes. On such systems one should increase the number of WAL buffers by modifying the wal_buffers parameter. When full_page_writes is set and the system is very busy, setting wal_buffers higher will help smooth response times during the period immediately following each checkpoint.

The commit_delay parameter defines for how many microseconds a group commit leader process will sleep after acquiring a lock within XLogFlush, while group commit followers queue up behind the leader. This delay allows other server processes to add their commit records to the WAL buffers so that all of them will be flushed by the leader's eventual sync operation. No sleep will occur if fsync

is not enabled, or if fewer than commit_siblings other sessions are currently in active transactions; this avoids sleeping when it's unlikely that any other session will commit soon. Note that on some platforms, the resolution of a sleep request is ten milliseconds, so that any nonzero `commit_delay` setting between 1 and 10000 microseconds would have the same effect. Note also that on some platforms, sleep operations may take slightly longer than requested by the parameter.

Since the purpose of `commit_delay` is to allow the cost of each flush operation to be amortized across concurrently committing transactions (potentially at the expense of transaction latency), it is necessary to quantify that cost before the setting can be chosen intelligently. The higher that cost is, the more effective `commit_delay` is expected to be in increasing transaction throughput, up to a point. The pg_test_fsync program can be used to measure the average time in microseconds that a single WAL flush operation takes. A value of half of the average time the program reports it takes to flush after a single 8kB write operation is often the most effective setting for `commit_delay`, so this value is recommended as the starting point to use when optimizing for a particular workload. While tuning `commit_delay` is particularly useful when the WAL log is stored on high-latency rotating disks, benefits can be significant even on storage media with very fast sync times, such as solid-state drives or RAID arrays with a battery-backed write cache; but this should definitely be tested against a representative workload. Higher values of `commit_siblings` should be used in such cases, whereas smaller `commit_siblings` values are often helpful on higher latency media. Note that it is quite possible that a setting of `commit_delay` that is too high can increase transaction latency by so much that total transaction throughput suffers.

When `commit_delay` is set to zero (the default), it is still possible for a form of group commit to occur, but each group will consist only of sessions that reach the point where they need to flush their commit records during the window in which the previous flush operation (if any) is occurring. At higher client counts a "gangway effect" tends to occur, so that the effects of group commit become significant even when `commit_delay` is zero, and thus explicitly setting `commit_delay` tends to help less. Setting `commit_delay` can only help when (1) there are some concurrently committing transactions, and (2) throughput is limited to some degree by commit rate; but with high rotational latency this setting can be effective in increasing transaction throughput with as few as two clients (that is, a single committing client with one sibling transaction).

The wal_sync_method parameter determines how PostgreSQL will ask the kernel to force WAL updates out to disk. All the options should be the same in terms of reliability, with the exception of `fsync_writethrough`, which can sometimes force a flush of the disk cache even when other options do not do so. However, it's quite platform-specific which one will be the fastest. You can test the speeds of different options using the pg_test_fsync program. Note that this parameter is irrelevant if `fsync` has been turned off.

Enabling the wal_debug configuration parameter (provided that PostgreSQL has been compiled with support for it) will result in each `XLogInsert` and `XLogFlush` WAL call being logged to the server log. This option might be replaced by a more general mechanism in the future.

29.5. WAL Internals

WAL is automatically enabled; no action is required from the administrator except ensuring that the disk-space requirements for the WAL logs are met, and that any necessary tuning is done (see Section 29.4).

WAL logs are stored in the directory `pg_xlog` under the data directory, as a set of segment files, normally each 16 MB in size (but the size can be changed by altering the `--with-wal-segsize` configure option when building the server). Each segment is divided into pages, normally 8 kB each (this size can be changed via the `--with-wal-blocksize` configure option). The log

record headers are described in `access/xlog.h`; the record content is dependent on the type of event that is being logged. Segment files are given ever-increasing numbers as names, starting at `000000010000000000000000`. The numbers do not wrap, but it will take a very, very long time to exhaust the available stock of numbers.

It is advantageous if the log is located on a different disk from the main database files. This can be achieved by moving the `pg_xlog` directory to another location (while the server is shut down, of course) and creating a symbolic link from the original location in the main data directory to the new location.

The aim of WAL is to ensure that the log is written before database records are altered, but this can be subverted by disk drives that falsely report a successful write to the kernel, when in fact they have only cached the data and not yet stored it on the disk. A power failure in such a situation might lead to irrecoverable data corruption. Administrators should try to ensure that disks holding PostgreSQL's WAL log files do not make such false reports. (See Section 29.1.)

After a checkpoint has been made and the log flushed, the checkpoint's position is saved in the file `pg_control`. Therefore, at the start of recovery, the server first reads `pg_control` and then the checkpoint record; then it performs the REDO operation by scanning forward from the log position indicated in the checkpoint record. Because the entire content of data pages is saved in the log on the first page modification after a checkpoint (assuming full_page_writes is not disabled), all pages changed since the checkpoint will be restored to a consistent state.

To deal with the case where `pg_control` is corrupt, we should support the possibility of scanning existing log segments in reverse order — newest to oldest — in order to find the latest checkpoint. This has not been implemented yet. `pg_control` is small enough (less than one disk page) that it is not subject to partial-write problems, and as of this writing there have been no reports of database failures due solely to the inability to read `pg_control` itself. So while it is theoretically a weak spot, `pg_control` does not seem to be a problem in practice.

Chapter 30. Regression Tests

The regression tests are a comprehensive set of tests for the SQL implementation in PostgreSQL. They test standard SQL operations as well as the extended capabilities of PostgreSQL.

30.1. Running the Tests

The regression tests can be run against an already installed and running server, or using a temporary installation within the build tree. Furthermore, there is a "parallel" and a "sequential" mode for running the tests. The sequential method runs each test script alone, while the parallel method starts up multiple server processes to run groups of tests in parallel. Parallel testing adds confidence that interprocess communication and locking are working correctly.

30.1.1. Running the Tests Against a Temporary Installation

To run the parallel regression tests after building but before installation, type:

```
make check
```

in the top-level directory. (Or you can change to `src/test/regress` and run the command there.) At the end you should see something like:

```
=======================
 All 115 tests passed.
=======================
```

or otherwise a note about which tests failed. See Section 30.2 below before assuming that a "failure" represents a serious problem.

Because this test method runs a temporary server, it will not work if you did the build as the root user, since the server will not start as root. Recommended procedure is not to do the build as root, or else to perform testing after completing the installation.

If you have configured PostgreSQL to install into a location where an older PostgreSQL installation already exists, and you perform `make check` before installing the new version, you might find that the tests fail because the new programs try to use the already-installed shared libraries. (Typical symptoms are complaints about undefined symbols.) If you wish to run the tests before overwriting the old installation, you'll need to build with `configure --disable-rpath`. It is not recommended that you use this option for the final installation, however.

The parallel regression test starts quite a few processes under your user ID. Presently, the maximum concurrency is twenty parallel test scripts, which means forty processes: there's a server process and a psql process for each test script. So if your system enforces a per-user limit on the number of processes, make sure this limit is at least fifty or so, else you might get random-seeming failures in the parallel test. If you are not in a position to raise the limit, you can cut down the degree of parallelism by setting the `MAX_CONNECTIONS` parameter. For example:

```
make MAX_CONNECTIONS=10 check
```

runs no more than ten tests concurrently.

30.1.2. Running the Tests Against an Existing Installation

To run the tests after installation (see Chapter 15), initialize a data area and start the server as explained in Chapter 17, then type:

```
make installcheck
```

or for a parallel test:

```
make installcheck-parallel
```

The tests will expect to contact the server at the local host and the default port number, unless directed otherwise by `PGHOST` and `PGPORT` environment variables. The tests will be run in a database named `regression`; any existing database by this name will be dropped. The tests will also transiently create some cluster-wide objects, such as user identities named `regressuser`*N*.

30.1.3. Additional Test Suites

The `make check` and `make installcheck` commands run only the "core" regression tests, which test built-in functionality of the PostgreSQL server. The source distribution also contains additional test suites, most of them having to do with add-on functionality such as optional procedural languages.

To run all test suites applicable to the modules that have been selected to be built, including the core tests, type one of these commands at the top of the build tree:

```
make check-world
make installcheck-world
```

These commands run the tests using temporary servers or an already-installed server, respectively, just as previously explained for `make check` and `make installcheck`. Other considerations are the same as previously explained for each method. Note that `make check-world` builds a separate temporary installation tree for each tested module, so it requires a great deal more time and disk space than `make installcheck-world`.

Alternatively, you can run individual test suites by typing `make check` or `make installcheck` in the appropriate subdirectory of the build tree. Keep in mind that `make installcheck` assumes you've installed the relevant module(s), not only the core server.

The additional tests that can be invoked this way include:

- Regression tests for optional procedural languages (other than PL/pgSQL, which is tested by the core tests). These are located under `src/pl`.
- Regression tests for `contrib` modules, located under `contrib`. Not all `contrib` modules have tests.
- Regression tests for the ECPG interface library, located in `src/interfaces/ecpg/test`.
- Tests stressing behavior of concurrent sessions, located in `src/test/isolation`.
- Tests of client programs under `src/bin`. See also Section 30.4.

When using `installcheck` mode, these tests will destroy any existing databases named `pl_regression`, `contrib_regression`, `isolationtest`, `regress1`, or `connectdb`, as well as `regression`.

30.1.4. Locale and Encoding

By default, tests using a temporary installation use the locale defined in the current environment and the corresponding database encoding as determined by `initdb`. It can be useful to test different locales by setting the appropriate environment variables, for example:

```
make check LANG=C
make check LC_COLLATE=en_US.utf8 LC_CTYPE=fr_CA.utf8
```

For implementation reasons, setting `LC_ALL` does not work for this purpose; all the other locale-related environment variables do work.

When testing against an existing installation, the locale is determined by the existing database cluster and cannot be set separately for the test run.

You can also choose the database encoding explicitly by setting the variable `ENCODING`, for example:

```
make check LANG=C ENCODING=EUC_JP
```

Setting the database encoding this way typically only makes sense if the locale is C; otherwise the encoding is chosen automatically from the locale, and specifying an encoding that does not match the locale will result in an error.

The database encoding can be set for tests against either a temporary or an existing installation, though in the latter case it must be compatible with the installation's locale.

30.1.5. Extra Tests

The core regression test suite contains a few test files that are not run by default, because they might be platform-dependent or take a very long time to run. You can run these or other extra test files by setting the variable `EXTRA_TESTS`. For example, to run the `numeric_big` test:

```
make check EXTRA_TESTS=numeric_big
```

To run the collation tests:

```
make check EXTRA_TESTS=collate.linux.utf8 LANG=en_US.utf8
```

The `collate.linux.utf8` test works only on Linux/glibc platforms, and only when run in a database that uses UTF-8 encoding.

30.1.6. Testing Hot Standby

The source distribution also contains regression tests for the static behavior of Hot Standby. These tests require a running primary server and a running standby server that is accepting new WAL changes from the primary (using either file-based log shipping or streaming replication). Those servers are not automatically created for you, nor is replication setup documented here. Please check the various sections of the documentation devoted to the required commands and related issues.

To run the Hot Standby tests, first create a database called `regression` on the primary:

```
psql -h primary -c "CREATE DATABASE regression"
```

Next, run the preparatory script `src/test/regress/sql/hs_primary_setup.sql` on the primary in the regression database, for example:

```
psql -h primary -f src/test/regress/sql/hs_primary_setup.sql regression
```

Allow these changes to propagate to the standby.

Now arrange for the default database connection to be to the standby server under test (for example, by setting the `PGHOST` and `PGPORT` environment variables). Finally, run `make standbycheck` in the regression directory:

```
cd src/test/regress
make standbycheck
```

Some extreme behaviors can also be generated on the primary using the script `src/test/regress/sql/hs_primary_extremes.sql` to allow the behavior of the standby to be tested.

30.2. Test Evaluation

Some properly installed and fully functional PostgreSQL installations can "fail" some of these regression tests due to platform-specific artifacts such as varying floating-point representation and message wording. The tests are currently evaluated using a simple `diff` comparison against the outputs generated on a reference system, so the results are sensitive to small system differences. When a test is reported as "failed", always examine the differences between expected and actual results; you might find that the differences are not significant. Nonetheless, we still strive to maintain accurate reference files across all supported platforms, so it can be expected that all tests pass.

The actual outputs of the regression tests are in files in the `src/test/regress/results` directory. The test script uses `diff` to compare each output file against the reference outputs stored in the `src/test/regress/expected` directory. Any differences are saved for your inspection in `src/test/regress/regression.diffs`. (When running a test suite other than the core tests, these files of course appear in the relevant subdirectory, not `src/test/regress`.)

If you don't like the `diff` options that are used by default, set the environment variable `PG_REGRESS_DIFF_OPTS`, for instance `PG_REGRESS_DIFF_OPTS='-u'`. (Or you can run `diff` yourself, if you prefer.)

If for some reason a particular platform generates a "failure" for a given test, but inspection of the output convinces you that the result is valid, you can add a new comparison file to silence the failure report in future test runs. See Section 30.3 for details.

30.2.1. Error Message Differences

Some of the regression tests involve intentional invalid input values. Error messages can come from either the PostgreSQL code or from the host platform system routines. In the latter case, the messages can vary between platforms, but should reflect similar information. These differences in messages will result in a "failed" regression test that can be validated by inspection.

30.2.2. Locale Differences

If you run the tests against a server that was initialized with a collation-order locale other than C, then there might be differences due to sort order and subsequent failures. The regression test suite is set

up to handle this problem by providing alternate result files that together are known to handle a large number of locales.

To run the tests in a different locale when using the temporary-installation method, pass the appropriate locale-related environment variables on the `make` command line, for example:

```
make check LANG=de_DE.utf8
```

(The regression test driver unsets `LC_ALL`, so it does not work to choose the locale using that variable.) To use no locale, either unset all locale-related environment variables (or set them to `C`) or use the following special invocation:

```
make check NO_LOCALE=1
```

When running the tests against an existing installation, the locale setup is determined by the existing installation. To change it, initialize the database cluster with a different locale by passing the appropriate options to `initdb`.

In general, it is advisable to try to run the regression tests in the locale setup that is wanted for production use, as this will exercise the locale- and encoding-related code portions that will actually be used in production. Depending on the operating system environment, you might get failures, but then you will at least know what locale-specific behaviors to expect when running real applications.

30.2.3. Date and Time Differences

Most of the date and time results are dependent on the time zone environment. The reference files are generated for time zone `PST8PDT` (Berkeley, California), and there will be apparent failures if the tests are not run with that time zone setting. The regression test driver sets environment variable `PGTZ` to `PST8PDT`, which normally ensures proper results.

30.2.4. Floating-Point Differences

Some of the tests involve computing 64-bit floating-point numbers (`double precision`) from table columns. Differences in results involving mathematical functions of `double precision` columns have been observed. The `float8` and `geometry` tests are particularly prone to small differences across platforms, or even with different compiler optimization settings. Human eyeball comparison is needed to determine the real significance of these differences which are usually 10 places to the right of the decimal point.

Some systems display minus zero as `-0`, while others just show `0`.

Some systems signal errors from `pow()` and `exp()` differently from the mechanism expected by the current PostgreSQL code.

30.2.5. Row Ordering Differences

You might see differences in which the same rows are output in a different order than what appears in the expected file. In most cases this is not, strictly speaking, a bug. Most of the regression test scripts are not so pedantic as to use an `ORDER BY` for every single `SELECT`, and so their result row orderings are not well-defined according to the SQL specification. In practice, since we are looking at the same queries being executed on the same data by the same software, we usually get the same result ordering on all platforms, so the lack of `ORDER BY` is not a problem. Some queries do exhibit cross-platform

ordering differences, however. When testing against an already-installed server, ordering differences can also be caused by non-C locale settings or non-default parameter settings, such as custom values of `work_mem` or the planner cost parameters.

Therefore, if you see an ordering difference, it's not something to worry about, unless the query does have an `ORDER BY` that your result is violating. However, please report it anyway, so that we can add an `ORDER BY` to that particular query to eliminate the bogus "failure" in future releases.

You might wonder why we don't order all the regression test queries explicitly to get rid of this issue once and for all. The reason is that that would make the regression tests less useful, not more, since they'd tend to exercise query plan types that produce ordered results to the exclusion of those that don't.

30.2.6. Insufficient Stack Depth

If the `errors` test results in a server crash at the `select infinite_recurse()` command, it means that the platform's limit on process stack size is smaller than the max_stack_depth parameter indicates. This can be fixed by running the server under a higher stack size limit (4MB is recommended with the default value of `max_stack_depth`). If you are unable to do that, an alternative is to reduce the value of `max_stack_depth`.

On platforms supporting `getrlimit()`, the server should automatically choose a safe value of `max_stack_depth`; so unless you've manually overridden this setting, a failure of this kind is a reportable bug.

30.2.7. The "random" Test

The `random` test script is intended to produce random results. In very rare cases, this causes that regression test to fail. Typing:

```
diff results/random.out expected/random.out
```

should produce only one or a few lines of differences. You need not worry unless the random test fails repeatedly.

30.2.8. Configuration Parameters

When running the tests against an existing installation, some non-default parameter settings could cause the tests to fail. For example, changing parameters such as `enable_seqscan` or `enable_indexscan` could cause plan changes that would affect the results of tests that use `EXPLAIN`.

30.3. Variant Comparison Files

Since some of the tests inherently produce environment-dependent results, we have provided ways to specify alternate "expected" result files. Each regression test can have several comparison files showing possible results on different platforms. There are two independent mechanisms for determining which comparison file is used for each test.

The first mechanism allows comparison files to be selected for specific platforms. There is a mapping file, `src/test/regress/resultmap`, that defines which comparison file to use for each platform. To eliminate bogus test "failures" for a particular platform, you first choose or make a variant result file, and then add a line to the `resultmap` file.

Each line in the mapping file is of the form

```
testname:output:platformpattern=comparisonfilename
```

The test name is just the name of the particular regression test module. The output value indicates which output file to check. For the standard regression tests, this is always `out`. The value corresponds to the file extension of the output file. The platform pattern is a pattern in the style of the Unix tool `expr` (that is, a regular expression with an implicit `^` anchor at the start). It is matched against the platform name as printed by `config.guess`. The comparison file name is the base name of the substitute result comparison file.

For example: some systems interpret very small floating-point values as zero, rather than reporting an underflow error. This causes a few differences in the `float8` regression test. Therefore, we provide a variant comparison file, `float8-small-is-zero.out`, which includes the results to be expected on these systems. To silence the bogus "failure" message on OpenBSD platforms, `resultmap` includes:

```
float8:out:i.86-.*-openbsd=float8-small-is-zero.out
```

which will trigger on any machine where the output of `config.guess` matches `i.86-.*-openbsd`. Other lines in `resultmap` select the variant comparison file for other platforms where it's appropriate.

The second selection mechanism for variant comparison files is much more automatic: it simply uses the "best match" among several supplied comparison files. The regression test driver script considers both the standard comparison file for a test, *`testname`*`.out`, and variant files named *`testname_digit`*`.out` (where the *`digit`* is any single digit `0-9`). If any such file is an exact match, the test is considered to pass; otherwise, the one that generates the shortest diff is used to create the failure report. (If `resultmap` includes an entry for the particular test, then the base *`testname`* is the substitute name given in `resultmap`.)

For example, for the `char` test, the comparison file `char.out` contains results that are expected in the `C` and `POSIX` locales, while the file `char_1.out` contains results sorted as they appear in many other locales.

The best-match mechanism was devised to cope with locale-dependent results, but it can be used in any situation where the test results cannot be predicted easily from the platform name alone. A limitation of this mechanism is that the test driver cannot tell which variant is actually "correct" for the current environment; it will just pick the variant that seems to work best. Therefore it is safest to use this mechanism only for variant results that you are willing to consider equally valid in all contexts.

30.4. TAP Tests

The client program tests under `src/bin` use the Perl TAP tools and are run by `prove`. You can pass command-line options to `prove` by setting the `make` variable `PROVE_FLAGS`, for example:

```
make -C src/bin check PROVE_FLAGS='--reverse'
```

The default is `--verbose`. See the manual page of `prove` for more information.

The tests written in Perl require the Perl module `IPC::Run`. This module is available from CPAN or an operating system package.

30.5. Test Coverage Examination

The PostgreSQL source code can be compiled with coverage testing instrumentation, so that it becomes possible to examine which parts of the code are covered by the regression tests or any other test suite that is run with the code. This is currently supported when compiling with GCC and requires the `gcov` and `lcov` programs.

A typical workflow would look like this:

```
./configure --enable-coverage ... OTHER OPTIONS ...
make
make check # or other test suite
make coverage-html
```

Then point your HTML browser to `coverage/index.html`. The `make` commands also work in subdirectories.

To reset the execution counts between test runs, run:

```
make coverage-clean
```

IV. Client Interfaces

This part describes the client programming interfaces distributed with PostgreSQL. Each of these chapters can be read independently. Note that there are many other programming interfaces for client programs that are distributed separately and contain their own documentation (Appendix H lists some of the more popular ones). Readers of this part should be familiar with using SQL commands to manipulate and query the database (see Part II) and of course with the programming language that the interface uses.

Chapter 31. libpq - C Library

libpq is the C application programmer's interface to PostgreSQL. libpq is a set of library functions that allow client programs to pass queries to the PostgreSQL backend server and to receive the results of these queries.

libpq is also the underlying engine for several other PostgreSQL application interfaces, including those written for C++, Perl, Python, Tcl and ECPG. So some aspects of libpq's behavior will be important to you if you use one of those packages. In particular, Section 31.14, Section 31.15 and Section 31.18 describe behavior that is visible to the user of any application that uses libpq.

Some short programs are included at the end of this chapter (Section 31.21) to show how to write programs that use libpq. There are also several complete examples of libpq applications in the directory `src/test/examples` in the source code distribution.

Client programs that use libpq must include the header file `libpq-fe.h` and must link with the libpq library.

31.1. Database Connection Control Functions

The following functions deal with making a connection to a PostgreSQL backend server. An application program can have several backend connections open at one time. (One reason to do that is to access more than one database.) Each connection is represented by a `PGconn` object, which is obtained from the function `PQconnectdb`, `PQconnectdbParams`, or `PQsetdbLogin`. Note that these functions will always return a non-null object pointer, unless perhaps there is too little memory even to allocate the `PGconn` object. The `PQstatus` function should be called to check the return value for a successful connection before queries are sent via the connection object.

> **Warning**
>
> On Unix, forking a process with open libpq connections can lead to unpredictable results because the parent and child processes share the same sockets and operating system resources. For this reason, such usage is not recommended, though doing an `exec` from the child process to load a new executable is safe.

Note: On Windows, there is a way to improve performance if a single database connection is repeatedly started and shutdown. Internally, libpq calls `WSAStartup()` and `WSACleanup()` for connection startup and shutdown, respectively. `WSAStartup()` increments an internal Windows library reference count which is decremented by `WSACleanup()`. When the reference count is just one, calling `WSACleanup()` frees all resources and all DLLs are unloaded. This is an expensive operation. To avoid this, an application can manually call `WSAStartup()` so resources will not be freed when the last database connection is closed.

`PQconnectdbParams`

Makes a new connection to the database server.

```
PGconn *PQconnectdbParams(const char * const *keywords,
                          const char * const *values,
                          int expand_dbname);
```

This function opens a new database connection using the parameters taken from two NULL-terminated arrays. The first, keywords, is defined as an array of strings, each one being a key word. The second, values, gives the value for each key word. Unlike PQsetdbLogin below, the parameter set can be extended without changing the function signature, so use of this function (or its nonblocking analogs PQconnectStartParams and PQconnectPoll) is preferred for new application programming.

The currently recognized parameter key words are listed in Section 31.1.2.

When expand_dbname is non-zero, the dbname key word value is allowed to be recognized as a connection string. Only the first occurrence of dbname is expanded this way, any subsequent dbname value is processed as plain database name. More details on the possible connection string formats appear in Section 31.1.1.

The passed arrays can be empty to use all default parameters, or can contain one or more parameter settings. They should be matched in length. Processing will stop at the first NULL element in the keywords array.

If any parameter is NULL or an emptry string, the corresponding environment variable (see Section 31.14) is checked. If the environment variable is not set either, then the indicated built-in defaults are used.

In general key words are processed from the beginning of these arrays in index order. The effect of this is that when key words are repeated, the last processed value is retained. Therefore, through careful placement of the dbname key word, it is possible to determine what may be overridden by a conninfo string, and what may not.

PQconnectdb

Makes a new connection to the database server.

```
PGconn *PQconnectdb(const char *conninfo);
```

This function opens a new database connection using the parameters taken from the string conninfo.

The passed string can be empty to use all default parameters, or it can contain one or more parameter settings separated by whitespace, or it can contain a URI. See Section 31.1.1 for details.

PQsetdbLogin

Makes a new connection to the database server.

```
PGconn *PQsetdbLogin(const char *pghost,
                     const char *pgport,
                     const char *pgoptions,
                     const char *pgtty,
                     const char *dbName,
                     const char *login,
                     const char *pwd);
```

This is the predecessor of PQconnectdb with a fixed set of parameters. It has the same functionality except that the missing parameters will always take on default values. Write NULL or an empty string for any one of the fixed parameters that is to be defaulted.

If the dbName contains an = sign or has a valid connection URI prefix, it is taken as a conninfo string in exactly the same way as if it had been passed to PQconnectdb, and the remaining parameters are then applied as specified for PQconnectdbParams.

PQsetdb

Makes a new connection to the database server.

```
PGconn *PQsetdb(char *pghost,
                char *pgport,
                char *pgoptions,
                char *pgtty,
                char *dbName);
```

This is a macro that calls PQsetdbLogin with null pointers for the login and pwd parameters. It is provided for backward compatibility with very old programs.

PQconnectStartParams
PQconnectStart
PQconnectPoll

Make a connection to the database server in a nonblocking manner.

```
PGconn *PQconnectStartParams(const char * const *keywords,
                             const char * const *values,
                             int expand_dbname);

PGconn *PQconnectStart(const char *conninfo);

PostgresPollingStatusType PQconnectPoll(PGconn *conn);
```

These three functions are used to open a connection to a database server such that your application's thread of execution is not blocked on remote I/O whilst doing so. The point of this approach is that the waits for I/O to complete can occur in the application's main loop, rather than down inside PQconnectdbParams or PQconnectdb, and so the application can manage this operation in parallel with other activities.

With PQconnectStartParams, the database connection is made using the parameters taken from the keywords and values arrays, and controlled by expand_dbname, as described above for PQconnectdbParams.

With PQconnectStart, the database connection is made using the parameters taken from the string conninfo as described above for PQconnectdb.

Neither PQconnectStartParams nor PQconnectStart nor PQconnectPoll will block, so long as a number of restrictions are met:

- The hostaddr and host parameters are used appropriately to ensure that name and reverse name queries are not made. See the documentation of these parameters in Section 31.1.2 for details.
- If you call PQtrace, ensure that the stream object into which you trace will not block.
- You ensure that the socket is in the appropriate state before calling PQconnectPoll, as described below.

Note: use of PQconnectStartParams is analogous to PQconnectStart shown below.

To begin a nonblocking connection request, call conn = PQconnectStart("*connection_info_string*"). If conn is null, then libpq has been unable to allocate a new PGconn structure. Otherwise, a valid PGconn pointer is returned (though not yet representing a valid connection to the database). On return from PQconnectStart, call status = PQstatus(conn). If status equals CONNECTION_BAD, PQconnectStart has failed.

If `PQconnectStart` succeeds, the next stage is to poll libpq so that it can proceed with the connection sequence. Use `PQsocket(conn)` to obtain the descriptor of the socket underlying the database connection. Loop thus: If `PQconnectPoll(conn)` last returned `PGRES_POLLING_READING`, wait until the socket is ready to read (as indicated by `select()`, `poll()`, or similar system function). Then call `PQconnectPoll(conn)` again. Conversely, if `PQconnectPoll(conn)` last returned `PGRES_POLLING_WRITING`, wait until the socket is ready to write, then call `PQconnectPoll(conn)` again. If you have yet to call `PQconnectPoll`, i.e., just after the call to `PQconnectStart`, behave as if it last returned `PGRES_POLLING_WRITING`. Continue this loop until `PQconnectPoll(conn)` returns `PGRES_POLLING_FAILED`, indicating the connection procedure has failed, or `PGRES_POLLING_OK`, indicating the connection has been successfully made.

At any time during connection, the status of the connection can be checked by calling `PQstatus`. If this call returns `CONNECTION_BAD`, then the connection procedure has failed; if the call returns `CONNECTION_OK`, then the connection is ready. Both of these states are equally detectable from the return value of `PQconnectPoll`, described above. Other states might also occur during (and only during) an asynchronous connection procedure. These indicate the current stage of the connection procedure and might be useful to provide feedback to the user for example. These statuses are:

`CONNECTION_STARTED`

Waiting for connection to be made.

`CONNECTION_MADE`

Connection OK; waiting to send.

`CONNECTION_AWAITING_RESPONSE`

Waiting for a response from the server.

`CONNECTION_AUTH_OK`

Received authentication; waiting for backend start-up to finish.

`CONNECTION_SSL_STARTUP`

Negotiating SSL encryption.

`CONNECTION_SETENV`

Negotiating environment-driven parameter settings.

Note that, although these constants will remain (in order to maintain compatibility), an application should never rely upon these occurring in a particular order, or at all, or on the status always being one of these documented values. An application might do something like this:

```
switch(PQstatus(conn))
{
        case CONNECTION_STARTED:
            feedback = "Connecting...";
            break;

        case CONNECTION_MADE:
            feedback = "Connected to server...";
            break;
.
.
.
        default:
            feedback = "Connecting...";
```

```
}
```

The `connect_timeout` connection parameter is ignored when using `PQconnectPoll`; it is the application's responsibility to decide whether an excessive amount of time has elapsed. Otherwise, `PQconnectStart` followed by a `PQconnectPoll` loop is equivalent to `PQconnectdb`.

Note that if `PQconnectStart` returns a non-null pointer, you must call `PQfinish` when you are finished with it, in order to dispose of the structure and any associated memory blocks. This must be done even if the connection attempt fails or is abandoned.

`PQconndefaults`

Returns the default connection options.

```
PQconninfoOption *PQconndefaults(void);

typedef struct
{
    char   *keyword;   /* The keyword of the option */
    char   *envvar;    /* Fallback environment variable name */
    char   *compiled;  /* Fallback compiled in default value */
    char   *val;       /* Option's current value, or NULL */
    char   *label;     /* Label for field in connect dialog */
    char   *dispchar;  /* Indicates how to display this field
                          in a connect dialog. Values are:
                          ""        Display entered value as is
                          "*"       Password field - hide value
                          "D"       Debug option - don't show by default */
    int     dispsize;  /* Field size in characters for dialog */
} PQconninfoOption;
```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and their current default values. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null `keyword` pointer. The null pointer is returned if memory could not be allocated. Note that the current default values (`val` fields) will depend on environment variables and other context. A missing or invalid service file will be silently ignored. Callers must treat the connection options data as read-only.

After processing the options array, free it by passing it to `PQconninfoFree`. If this is not done, a small amount of memory is leaked for each call to `PQconndefaults`.

`PQconninfo`

Returns the connection options used by a live connection.

```
PQconninfoOption *PQconninfo(PGconn *conn);
```

Returns a connection options array. This can be used to determine all possible `PQconnectdb` options and the values that were used to connect to the server. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null `keyword` pointer. All notes above for `PQconndefaults` also apply to the result of `PQconninfo`.

`PQconninfoParse`

Returns parsed connection options from the provided connection string.

```
PQconninfoOption *PQconninfoParse(const char *conninfo, char **errmsg);
```

Parses a connection string and returns the resulting options as an array; or returns `NULL` if there is a problem with the connection string. This function can be used to extract the `PQconnectdb` options in the provided connection string. The return value points to an array of `PQconninfoOption` structures, which ends with an entry having a null `keyword` pointer.

All legal options will be present in the result array, but the PQconninfoOption for any option not present in the connection string will have val set to NULL; default values are not inserted.

If errmsg is not NULL, then *errmsg is set to NULL on success, else to a malloc'd error string explaining the problem. (It is also possible for *errmsg to be set to NULL and the function to return NULL; this indicates an out-of-memory condition.)

After processing the options array, free it by passing it to PQconninfoFree. If this is not done, some memory is leaked for each call to PQconninfoParse. Conversely, if an error occurs and errmsg is not NULL, be sure to free the error string using PQfreemem.

PQfinish

Closes the connection to the server. Also frees memory used by the PGconn object.

```
void PQfinish(PGconn *conn);
```

Note that even if the server connection attempt fails (as indicated by PQstatus), the application should call PQfinish to free the memory used by the PGconn object. The PGconn pointer must not be used again after PQfinish has been called.

PQreset

Resets the communication channel to the server.

```
void PQreset(PGconn *conn);
```

This function will close the connection to the server and attempt to reestablish a new connection to the same server, using all the same parameters previously used. This might be useful for error recovery if a working connection is lost.

PQresetStart
PQresetPoll

Reset the communication channel to the server, in a nonblocking manner.

```
int PQresetStart(PGconn *conn);

PostgresPollingStatusType PQresetPoll(PGconn *conn);
```

These functions will close the connection to the server and attempt to reestablish a new connection to the same server, using all the same parameters previously used. This can be useful for error recovery if a working connection is lost. They differ from PQreset (above) in that they act in a nonblocking manner. These functions suffer from the same restrictions as PQconnectStartParams, PQconnectStart and PQconnectPoll.

To initiate a connection reset, call PQresetStart. If it returns 0, the reset has failed. If it returns 1, poll the reset using PQresetPoll in exactly the same way as you would create the connection using PQconnectPoll.

PQpingParams

PQpingParams reports the status of the server. It accepts connection parameters identical to those of PQconnectdbParams, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

```
PGPing PQpingParams(const char * const *keywords,
                    const char * const *values,
                    int expand_dbname);
```

The function returns one of the following values:

`PQPING_OK`

The server is running and appears to be accepting connections.

`PQPING_REJECT`

The server is running but is in a state that disallows connections (startup, shutdown, or crash recovery).

`PQPING_NO_RESPONSE`

The server could not be contacted. This might indicate that the server is not running, or that there is something wrong with the given connection parameters (for example, wrong port number), or that there is a network connectivity problem (for example, a firewall blocking the connection request).

`PQPING_NO_ATTEMPT`

No attempt was made to contact the server, because the supplied parameters were obviously incorrect or there was some client-side problem (for example, out of memory).

`PQping`

`PQping` reports the status of the server. It accepts connection parameters identical to those of `PQconnectdb`, described above. It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

```
PGPing PQping(const char *conninfo);
```

The return values are the same as for `PQpingParams`.

31.1.1. Connection Strings

Several libpq functions parse a user-specified string to obtain connection parameters. There are two accepted formats for these strings: plain `keyword = value` strings and RFC 3986[1] URIs.

31.1.1.1. Keyword/Value Connection Strings

In the first format, each parameter setting is in the form `keyword = value`. Spaces around the equal sign are optional. To write an empty value, or a value containing spaces, surround it with single quotes, e.g., `keyword = 'a value'`. Single quotes and backslashes within the value must be escaped with a backslash, i.e., `\'` and `\\`.

Example:

```
host=localhost port=5432 dbname=mydb connect_timeout=10
```

The recognized parameter key words are listed in Section 31.1.2.

1. http://www.ietf.org/rfc/rfc3986.txt

31.1.1.2. Connection URIs

The general form for a connection URI is:

```
postgresql://[user[:password]@][netloc][:port][/dbname][?param1=value1&...]
```

The URI scheme designator can be either `postgresql://` or `postgres://`. Each of the URI parts is optional. The following examples illustrate valid URI syntax uses:

```
postgresql://
postgresql://localhost
postgresql://localhost:5433
postgresql://localhost/mydb
postgresql://user@localhost
postgresql://user:secret@localhost
postgresql://other@localhost/otherdb?connect_timeout=10&application_name=myapp
```

Components of the hierarchical part of the URI can also be given as parameters. For example:

```
postgresql:///mydb?host=localhost&port=5433
```

Percent-encoding may be used to include symbols with special meaning in any of the URI parts.

Any connection parameters not corresponding to key words listed in Section 31.1.2 are ignored and a warning message about them is sent to `stderr`.

For improved compatibility with JDBC connection URIs, instances of parameter `ssl=true` are translated into `sslmode=require`.

The host part may be either host name or an IP address. To specify an IPv6 host address, enclose it in square brackets:

```
postgresql://[2001:db8::1234]/database
```

The host component is interpreted as described for the parameter host. In particular, a Unix-domain socket connection is chosen if the host part is either empty or starts with a slash, otherwise a TCP/IP connection is initiated. Note, however, that the slash is a reserved character in the hierarchical part of the URI. So, to specify a non-standard Unix-domain socket directory, either omit the host specification in the URI and specify the host as a parameter, or percent-encode the path in the host component of the URI:

```
postgresql:///dbname?host=/var/lib/postgresql
postgresql://%2Fvar%2Flib%2Fpostgresql/dbname
```

31.1.2. Parameter Key Words

The currently recognized parameter key words are:

`host`

Name of host to connect to. If this begins with a slash, it specifies Unix-domain communication rather than TCP/IP communication; the value is the name of the directory in which the socket file is stored. The default behavior when `host` is not specified is to connect to a Unix-domain socket in `/tmp` (or whatever socket directory was specified when PostgreSQL was built). On machines without Unix-domain sockets, the default is to connect to `localhost`.

`hostaddr`

Numeric IP address of host to connect to. This should be in the standard IPv4 address format, e.g., `172.28.40.9`. If your machine supports IPv6, you can also use those addresses. TCP/IP communication is always used when a nonempty string is specified for this parameter.

Using `hostaddr` instead of `host` allows the application to avoid a host name look-up, which might be important in applications with time constraints. However, a host name is required for GSSAPI or SSPI authentication methods, as well as for `verify-full` SSL certificate verification. The following rules are used:

- If `host` is specified without `hostaddr`, a host name lookup occurs.
- If `hostaddr` is specified without `host`, the value for `hostaddr` gives the server network address. The connection attempt will fail if the authentication method requires a host name.
- If both `host` and `hostaddr` are specified, the value for `hostaddr` gives the server network address. The value for `host` is ignored unless the authentication method requires it, in which case it will be used as the host name.

Note that authentication is likely to fail if `host` is not the name of the server at network address `hostaddr`. Also, note that `host` rather than `hostaddr` is used to identify the connection in `~/.pgpass` (see Section 31.15).

Without either a host name or host address, libpq will connect using a local Unix-domain socket; or on machines without Unix-domain sockets, it will attempt to connect to `localhost`.

`port`

Port number to connect to at the server host, or socket file name extension for Unix-domain connections.

`dbname`

The database name. Defaults to be the same as the user name. In certain contexts, the value is checked for extended formats; see Section 31.1.1 for more details on those.

`user`

PostgreSQL user name to connect as. Defaults to be the same as the operating system name of the user running the application.

`password`

Password to be used if the server demands password authentication.

`connect_timeout`

Maximum wait for connection, in seconds (write as a decimal integer string). Zero or not specified means wait indefinitely. It is not recommended to use a timeout of less than 2 seconds.

client_encoding

This sets the client_encoding configuration parameter for this connection. In addition to the values accepted by the corresponding server option, you can use auto to determine the right encoding from the current locale in the client (LC_CTYPE environment variable on Unix systems).

options

Adds command-line options to send to the server at run-time. For example, setting this to -c geqo=off sets the session's value of the geqo parameter to off. For a detailed discussion of the available options, consult Chapter 18.

application_name

Specifies a value for the application_name configuration parameter.

fallback_application_name

Specifies a fallback value for the application_name configuration parameter. This value will be used if no value has been given for application_name via a connection parameter or the PGAPPNAME environment variable. Specifying a fallback name is useful in generic utility programs that wish to set a default application name but allow it to be overridden by the user.

keepalives

Controls whether client-side TCP keepalives are used. The default value is 1, meaning on, but you can change this to 0, meaning off, if keepalives are not wanted. This parameter is ignored for connections made via a Unix-domain socket.

keepalives_idle

Controls the number of seconds of inactivity after which TCP should send a keepalive message to the server. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where the TCP_KEEPIDLE or TCP_KEEPALIVE socket option is available, and on Windows; on other systems, it has no effect.

keepalives_interval

Controls the number of seconds after which a TCP keepalive message that is not acknowledged by the server should be retransmitted. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where the TCP_KEEPINTVL socket option is available, and on Windows; on other systems, it has no effect.

keepalives_count

Controls the number of TCP keepalives that can be lost before the client's connection to the server is considered dead. A value of zero uses the system default. This parameter is ignored for connections made via a Unix-domain socket, or if keepalives are disabled. It is only supported on systems where the TCP_KEEPCNT socket option is available; on other systems, it has no effect.

tty

Ignored (formerly, this specified where to send server debug output).

sslmode

This option determines whether or with what priority a secure SSL TCP/IP connection will be

negotiated with the server. There are six modes:

`disable`

only try a non-SSL connection

`allow`

first try a non-SSL connection; if that fails, try an SSL connection

`prefer` (default)

first try an SSL connection; if that fails, try a non-SSL connection

`require`

only try an SSL connection. If a root CA file is present, verify the certificate in the same way as if `verify-ca` was specified

`verify-ca`

only try an SSL connection, and verify that the server certificate is issued by a trusted certificate authority (CA)

`verify-full`

only try an SSL connection, verify that the server certificate is issued by a trusted CA and that the server host name matches that in the certificate

See Section 31.18 for a detailed description of how these options work.

`sslmode` is ignored for Unix domain socket communication. If PostgreSQL is compiled without SSL support, using options `require`, `verify-ca`, or `verify-full` will cause an error, while options `allow` and `prefer` will be accepted but libpq will not actually attempt an SSL connection.

`requiressl`

This option is deprecated in favor of the `sslmode` setting.

If set to 1, an SSL connection to the server is required (this is equivalent to `sslmode require`). libpq will then refuse to connect if the server does not accept an SSL connection. If set to 0 (default), libpq will negotiate the connection type with the server (equivalent to `sslmode prefer`). This option is only available if PostgreSQL is compiled with SSL support.

`sslcompression`

If set to 1 (default), data sent over SSL connections will be compressed (this requires OpenSSL version 0.9.8 or later). If set to 0, compression will be disabled (this requires OpenSSL 1.0.0 or later). This parameter is ignored if a connection without SSL is made, or if the version of OpenSSL used does not support it.

Compression uses CPU time, but can improve throughput if the network is the bottleneck. Disabling compression can improve response time and throughput if CPU performance is the limiting factor.

`sslcert`

This parameter specifies the file name of the client SSL certificate, replacing the default `~/.postgresql/postgresql.crt`. This parameter is ignored if an SSL connection is not made.

`sslkey`

This parameter specifies the location for the secret key used for the client certificate. It can either specify a file name that will be used instead of the default `~/.postgresql/postgresql.key`,

or it can specify a key obtained from an external "engine" (engines are OpenSSL loadable modules). An external engine specification should consist of a colon-separated engine name and an engine-specific key identifier. This parameter is ignored if an SSL connection is not made.

`sslrootcert`

This parameter specifies the name of a file containing SSL certificate authority (CA) certificate(s). If the file exists, the server's certificate will be verified to be signed by one of these authorities. The default is `~/.postgresql/root.crt`.

`sslcrl`

This parameter specifies the file name of the SSL certificate revocation list (CRL). Certificates listed in this file, if it exists, will be rejected while attempting to authenticate the server's certificate. The default is `~/.postgresql/root.crl`.

`requirepeer`

This parameter specifies the operating-system user name of the server, for example `requirepeer=postgres`. When making a Unix-domain socket connection, if this parameter is set, the client checks at the beginning of the connection that the server process is running under the specified user name; if it is not, the connection is aborted with an error. This parameter can be used to provide server authentication similar to that available with SSL certificates on TCP/IP connections. (Note that if the Unix-domain socket is in `/tmp` or another publicly writable location, any user could start a server listening there. Use this parameter to ensure that you are connected to a server run by a trusted user.) This option is only supported on platforms for which the `peer` authentication method is implemented; see Section 19.3.6.

`krbsrvname`

Kerberos service name to use when authenticating with GSSAPI. This must match the service name specified in the server configuration for Kerberos authentication to succeed. (See also Section 19.3.3.)

`gsslib`

GSS library to use for GSSAPI authentication. Only used on Windows. Set to `gssapi` to force libpq to use the GSSAPI library for authentication instead of the default SSPI.

`service`

Service name to use for additional parameters. It specifies a service name in `pg_service.conf` that holds additional connection parameters. This allows applications to specify only a service name so connection parameters can be centrally maintained. See Section 31.16.

31.2. Connection Status Functions

These functions can be used to interrogate the status of an existing database connection object.

Tip: libpq application programmers should be careful to maintain the `PGconn` abstraction. Use the accessor functions described below to get at the contents of `PGconn`. Reference to internal `PGconn` fields using `libpq-int.h` is not recommended because they are subject to change in the future.

The following functions return parameter values established at connection. These values are fixed for the life of the PGconn object.

PQdb

Returns the database name of the connection.

```
char *PQdb(const PGconn *conn);
```

PQuser

Returns the user name of the connection.

```
char *PQuser(const PGconn *conn);
```

PQpass

Returns the password of the connection.

```
char *PQpass(const PGconn *conn);
```

PQhost

Returns the server host name of the connection.

```
char *PQhost(const PGconn *conn);
```

PQport

Returns the port of the connection.

```
char *PQport(const PGconn *conn);
```

PQtty

Returns the debug TTY of the connection. (This is obsolete, since the server no longer pays attention to the TTY setting, but the function remains for backward compatibility.)

```
char *PQtty(const PGconn *conn);
```

PQoptions

Returns the command-line options passed in the connection request.

```
char *PQoptions(const PGconn *conn);
```

The following functions return status data that can change as operations are executed on the PGconn object.

PQstatus

Returns the status of the connection.

```
ConnStatusType PQstatus(const PGconn *conn);
```

The status can be one of a number of values. However, only two of these are seen outside of an asynchronous connection procedure: CONNECTION_OK and CONNECTION_BAD. A good connection to the database has the status CONNECTION_OK. A failed connection attempt is signaled by status CONNECTION_BAD. Ordinarily, an OK status will remain so until PQfinish, but a communications failure might result in the status changing to CONNECTION_BAD prematurely. In that case the application could try to recover by calling PQreset.

See the entry for PQconnectStartParams, PQconnectStart and PQconnectPoll with regards to other status codes that might be returned.

`PQtransactionStatus`

Returns the current in-transaction status of the server.

```
PGTransactionStatusType PQtransactionStatus(const PGconn *conn);
```

The status can be `PQTRANS_IDLE` (currently idle), `PQTRANS_ACTIVE` (a command is in progress), `PQTRANS_INTRANS` (idle, in a valid transaction block), or `PQTRANS_INERROR` (idle, in a failed transaction block). `PQTRANS_UNKNOWN` is reported if the connection is bad. `PQTRANS_ACTIVE` is reported only when a query has been sent to the server and not yet completed.

`PQparameterStatus`

Looks up a current parameter setting of the server.

```
const char *PQparameterStatus(const PGconn *conn, const char *paramName);
```

Certain parameter values are reported by the server automatically at connection startup or whenever their values change. `PQparameterStatus` can be used to interrogate these settings. It returns the current value of a parameter if known, or `NULL` if the parameter is not known.

Parameters reported as of the current release include `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. (`server_encoding`, `TimeZone`, and `integer_datetimes` were not reported by releases before 8.0; `standard_conforming_strings` was not reported by releases before 8.1; `IntervalStyle` was not reported by releases before 8.4; `application_name` was not reported by releases before 9.0.) Note that `server_version`, `server_encoding` and `integer_datetimes` cannot change after startup.

Pre-3.0-protocol servers do not report parameter settings, but libpq includes logic to obtain values for `server_version` and `client_encoding` anyway. Applications are encouraged to use `PQparameterStatus` rather than *ad hoc* code to determine these values. (Beware however that on a pre-3.0 connection, changing `client_encoding` via `SET` after connection startup will not be reflected by `PQparameterStatus`.) For `server_version`, see also `PQserverVersion`, which returns the information in a numeric form that is much easier to compare against.

If no value for `standard_conforming_strings` is reported, applications can assume it is `off`, that is, backslashes are treated as escapes in string literals. Also, the presence of this parameter can be taken as an indication that the escape string syntax (`E'...'`) is accepted.

Although the returned pointer is declared `const`, it in fact points to mutable storage associated with the `PGconn` structure. It is unwise to assume the pointer will remain valid across queries.

`PQprotocolVersion`

Interrogates the frontend/backend protocol being used.

```
int PQprotocolVersion(const PGconn *conn);
```

Applications might wish to use this function to determine whether certain features are supported. Currently, the possible values are 2 (2.0 protocol), 3 (3.0 protocol), or zero (connection bad). The protocol version will not change after connection startup is complete, but it could theoretically change during a connection reset. The 3.0 protocol will normally be used when communicating with PostgreSQL 7.4 or later servers; pre-7.4 servers support only protocol 2.0. (Protocol 1.0 is obsolete and not supported by libpq.)

`PQserverVersion`

Returns an integer representing the backend version.

```
int PQserverVersion(const PGconn *conn);
```

Applications might use this function to determine the version of the database server they are connected to. The number is formed by converting the major, minor, and revision numbers into two-decimal-digit numbers and appending them together. For example, version 8.1.5 will be returned as 80105, and version 8.2 will be returned as 80200 (leading zeroes are not shown). Zero is returned if the connection is bad.

`PQerrorMessage`

Returns the error message most recently generated by an operation on the connection.

```
char *PQerrorMessage(const PGconn *conn);
```

Nearly all libpq functions will set a message for `PQerrorMessage` if they fail. Note that by libpq convention, a nonempty `PQerrorMessage` result can consist of multiple lines, and will include a trailing newline. The caller should not free the result directly. It will be freed when the associated `PGconn` handle is passed to `PQfinish`. The result string should not be expected to remain the same across operations on the `PGconn` structure.

`PQsocket`

Obtains the file descriptor number of the connection socket to the server. A valid descriptor will be greater than or equal to 0; a result of -1 indicates that no server connection is currently open. (This will not change during normal operation, but could change during connection setup or reset.)

```
int PQsocket(const PGconn *conn);
```

`PQbackendPID`

Returns the process ID (PID) of the backend process handling this connection.

```
int PQbackendPID(const PGconn *conn);
```

The backend PID is useful for debugging purposes and for comparison to `NOTIFY` messages (which include the PID of the notifying backend process). Note that the PID belongs to a process executing on the database server host, not the local host!

`PQconnectionNeedsPassword`

Returns true (1) if the connection authentication method required a password, but none was available. Returns false (0) if not.

```
int PQconnectionNeedsPassword(const PGconn *conn);
```

This function can be applied after a failed connection attempt to decide whether to prompt the user for a password.

`PQconnectionUsedPassword`

Returns true (1) if the connection authentication method used a password. Returns false (0) if not.

```
int PQconnectionUsedPassword(const PGconn *conn);
```

This function can be applied after either a failed or successful connection attempt to detect whether the server demanded a password.

`PQgetssl`

Returns the SSL structure used in the connection, or null if SSL is not in use.

```
void *PQgetssl(const PGconn *conn);
```

This structure can be used to verify encryption levels, check server certificates, and more. Refer to the OpenSSL documentation for information about this structure.

The actual return value is of type `SSL *`, where `SSL` is a type defined by the OpenSSL library, but it is not declared this way to avoid requiring the OpenSSL header files. To use this function, code along the following lines could be used:

```
#include <libpq-fe.h>
#include <openssl/ssl.h>

...

    SSL *ssl;

    dbconn = PQconnectdb(...);
    ...

    ssl = PQgetssl(dbconn);
    if (ssl)
    {
        /* use OpenSSL functions to access ssl */
    }
```

31.3. Command Execution Functions

Once a connection to a database server has been successfully established, the functions described here are used to perform SQL queries and commands.

31.3.1. Main Functions

`PQexec`

Submits a command to the server and waits for the result.

```
PGresult *PQexec(PGconn *conn, const char *command);
```

Returns a `PGresult` pointer or possibly a null pointer. A non-null pointer will generally be returned except in out-of-memory conditions or serious errors such as inability to send the command to the server. The `PQresultStatus` function should be called to check the return value for any errors (including the value of a null pointer, in which case it will return `PGRES_FATAL_ERROR`). Use `PQerrorMessage` to get more information about such errors.

The command string can include multiple SQL commands (separated by semicolons). Multiple queries sent in a single `PQexec` call are processed in a single transaction, unless there are explicit `BEGIN`/`COMMIT` commands included in the query string to divide it into multiple transactions. Note however that the returned `PGresult` structure describes only the result of the last command executed from the string. Should one of the commands fail, processing of the string stops with it and the returned `PGresult` describes the error condition.

`PQexecParams`

Submits a command to the server and waits for the result, with the ability to pass parameters separately from the SQL command text.

```
PGresult *PQexecParams(PGconn *conn,
                       const char *command,
```

```
                        int nParams,
                        const Oid *paramTypes,
                        const char * const *paramValues,
                        const int *paramLengths,
                        const int *paramFormats,
                        int resultFormat);
```

`PQexecParams` is like `PQexec`, but offers additional functionality: parameter values can be specified separately from the command string proper, and query results can be requested in either text or binary format. `PQexecParams` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function arguments are:

`conn`

The connection object to send the command through.

`command`

The SQL command string to be executed. If parameters are used, they are referred to in the command string as `$1`, `$2`, etc.

`nParams`

The number of parameters supplied; it is the length of the arrays `paramTypes[]`, `paramValues[]`, `paramLengths[]`, and `paramFormats[]`. (The array pointers can be `NULL` when `nParams` is zero.)

`paramTypes[]`

Specifies, by OID, the data types to be assigned to the parameter symbols. If `paramTypes` is `NULL`, or any particular element in the array is zero, the server infers a data type for the parameter symbol in the same way it would do for an untyped literal string.

`paramValues[]`

Specifies the actual values of the parameters. A null pointer in this array means the corresponding parameter is null; otherwise the pointer points to a zero-terminated text string (for text format) or binary data in the format expected by the server (for binary format).

`paramLengths[]`

Specifies the actual data lengths of binary-format parameters. It is ignored for null parameters and text-format parameters. The array pointer can be null when there are no binary parameters.

`paramFormats[]`

Specifies whether parameters are text (put a zero in the array entry for the corresponding parameter) or binary (put a one in the array entry for the corresponding parameter). If the array pointer is null then all parameters are presumed to be text strings.

Values passed in binary format require knowledge of the internal representation expected by the backend. For example, integers must be passed in network byte order. Passing `numeric` values requires knowledge of the server storage format, as implemented in `src/backend/utils/adt/numeric.c::numeric_send()` and `src/backend/utils/adt/numeric.c::numeric_recv()`.

`resultFormat`

Specify zero to obtain results in text format, or one to obtain results in binary format. (There is not currently a provision to obtain different result columns in different formats, although that is possible in the underlying protocol.)

The primary advantage of `PQexecParams` over `PQexec` is that parameter values can be separated from the command string, thus avoiding the need for tedious and error-prone quoting and escaping.

Unlike `PQexec`, `PQexecParams` allows at most one SQL command in the given string. (There can be semicolons in it, but not more than one nonempty command.) This is a limitation of the underlying protocol, but has some usefulness as an extra defense against SQL-injection attacks.

Tip: Specifying parameter types via OIDs is tedious, particularly if you prefer not to hard-wire particular OID values into your program. However, you can avoid doing so even in cases where the server by itself cannot determine the type of the parameter, or chooses a different type than you want. In the SQL command text, attach an explicit cast to the parameter symbol to show what data type you will send. For example:

```
SELECT * FROM mytable WHERE x = $1::bigint;
```

This forces parameter `$1` to be treated as `bigint`, whereas by default it would be assigned the same type as `x`. Forcing the parameter type decision, either this way or by specifying a numeric type OID, is strongly recommended when sending parameter values in binary format, because binary format has less redundancy than text format and so there is less chance that the server will detect a type mismatch mistake for you.

`PQprepare`

Submits a request to create a prepared statement with the given parameters, and waits for completion.

```
PGresult *PQprepare(PGconn *conn,
                    const char *stmtName,
                    const char *query,
                    int nParams,
                    const Oid *paramTypes);
```

`PQprepare` creates a prepared statement for later execution with `PQexecPrepared`. This feature allows commands that will be used repeatedly to be parsed and planned just once, rather than each time they are executed. `PQprepare` is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The function creates a prepared statement named `stmtName` from the `query` string, which must contain a single SQL command. `stmtName` can be `""` to create an unnamed statement, in which case any pre-existing unnamed statement is automatically replaced; otherwise it is an error if the statement name is already defined in the current session. If any parameters are used, they are referred to in the query as `$1`, `$2`, etc. `nParams` is the number of parameters for which types are pre-specified in the array `paramTypes[]`. (The array pointer can be `NULL` when `nParams` is zero.) `paramTypes[]` specifies, by OID, the data types to be assigned to the parameter symbols. If `paramTypes` is `NULL`, or any particular element in the array is zero, the server assigns a data type to the parameter symbol in the same way it would do for an untyped literal string. Also, the

query can use parameter symbols with numbers higher than nParams; data types will be inferred for these symbols as well. (See PQdescribePrepared for a means to find out what data types were inferred.)

As with PQexec, the result is normally a PGresult object whose contents indicate server-side success or failure. A null result indicates out-of-memory or inability to send the command at all. Use PQerrorMessage to get more information about such errors.

Prepared statements for use with PQexecPrepared can also be created by executing SQL PREPARE statements. Also, although there is no libpq function for deleting a prepared statement, the SQL DEALLOCATE statement can be used for that purpose.

PQexecPrepared

Sends a request to execute a prepared statement with given parameters, and waits for the result.

```
PGresult *PQexecPrepared(PGconn *conn,
                         const char *stmtName,
                         int nParams,
                         const char * const *paramValues,
                         const int *paramLengths,
                         const int *paramFormats,
                         int resultFormat);
```

PQexecPrepared is like PQexecParams, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. This feature allows commands that will be used repeatedly to be parsed and planned just once, rather than each time they are executed. The statement must have been prepared previously in the current session. PQexecPrepared is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

The parameters are identical to PQexecParams, except that the name of a prepared statement is given instead of a query string, and the paramTypes[] parameter is not present (it is not needed since the prepared statement's parameter types were determined when it was created).

PQdescribePrepared

Submits a request to obtain information about the specified prepared statement, and waits for completion.

```
PGresult *PQdescribePrepared(PGconn *conn, const char *stmtName);
```

PQdescribePrepared allows an application to obtain information about a previously prepared statement. PQdescribePrepared is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

stmtName can be "" or NULL to reference the unnamed statement, otherwise it must be the name of an existing prepared statement. On success, a PGresult with status PGRES_COMMAND_OK is returned. The functions PQnparams and PQparamtype can be applied to this PGresult to obtain information about the parameters of the prepared statement, and the functions PQnfields, PQfname, PQftype, etc provide information about the result columns (if any) of the statement.

PQdescribePortal

Submits a request to obtain information about the specified portal, and waits for completion.

```
PGresult *PQdescribePortal(PGconn *conn, const char *portalName);
```

PQdescribePortal allows an application to obtain information about a previously created portal. (libpq does not provide any direct access to portals, but you can use this function to inspect the properties of a cursor created with a DECLARE CURSOR SQL command.) PQdescribePortal is supported only in protocol 3.0 and later connections; it will fail when using protocol 2.0.

portalName can be "" or NULL to reference the unnamed portal, otherwise it must be the name of an existing portal. On success, a PGresult with status PGRES_COMMAND_OK is returned. The functions PQnfields, PQfname, PQftype, etc can be applied to the PGresult to obtain information about the result columns (if any) of the portal.

The PGresult structure encapsulates the result returned by the server. libpq application programmers should be careful to maintain the PGresult abstraction. Use the accessor functions below to get at the contents of PGresult. Avoid directly referencing the fields of the PGresult structure because they are subject to change in the future.

PQresultStatus

Returns the result status of the command.

```
ExecStatusType PQresultStatus(const PGresult *res);
```

PQresultStatus can return one of the following values:

PGRES_EMPTY_QUERY

The string sent to the server was empty.

PGRES_COMMAND_OK

Successful completion of a command returning no data.

PGRES_TUPLES_OK

Successful completion of a command returning data (such as a SELECT or SHOW).

PGRES_COPY_OUT

Copy Out (from server) data transfer started.

PGRES_COPY_IN

Copy In (to server) data transfer started.

PGRES_BAD_RESPONSE

The server's response was not understood.

PGRES_NONFATAL_ERROR

A nonfatal error (a notice or warning) occurred.

PGRES_FATAL_ERROR

A fatal error occurred.

PGRES_COPY_BOTH

Copy In/Out (to and from server) data transfer started. This feature is currently used only for streaming replication, so this status should not occur in ordinary applications.

PGRES_SINGLE_TUPLE

The PGresult contains a single result tuple from the current command. This status occurs only when single-row mode has been selected for the query (see Section 31.5).

If the result status is PGRES_TUPLES_OK or PGRES_SINGLE_TUPLE, then the functions described below can be used to retrieve the rows returned by the query. Note that a SELECT command that happens to retrieve zero rows still shows PGRES_TUPLES_OK. PGRES_COMMAND_OK is for commands that can never return rows (INSERT or UPDATE without a RETURNING clause, etc.). A response of PGRES_EMPTY_QUERY might indicate a bug in the client software.

A result of status PGRES_NONFATAL_ERROR will never be returned directly by PQexec or other query execution functions; results of this kind are instead passed to the notice processor (see Section 31.12).

PQresStatus

Converts the enumerated type returned by PQresultStatus into a string constant describing the status code. The caller should not free the result.

```
char *PQresStatus(ExecStatusType status);
```

PQresultErrorMessage

Returns the error message associated with the command, or an empty string if there was no error.

```
char *PQresultErrorMessage(const PGresult *res);
```

If there was an error, the returned string will include a trailing newline. The caller should not free the result directly. It will be freed when the associated PGresult handle is passed to PQclear.

Immediately following a PQexec or PQgetResult call, PQerrorMessage (on the connection) will return the same string as PQresultErrorMessage (on the result). However, a PGresult will retain its error message until destroyed, whereas the connection's error message will change when subsequent operations are done. Use PQresultErrorMessage when you want to know the status associated with a particular PGresult; use PQerrorMessage when you want to know the status from the latest operation on the connection.

PQresultErrorField

Returns an individual field of an error report.

```
char *PQresultErrorField(const PGresult *res, int fieldcode);
```

fieldcode is an error field identifier; see the symbols listed below. NULL is returned if the PGresult is not an error or warning result, or does not include the specified field. Field values will normally not include a trailing newline. The caller should not free the result directly. It will be freed when the associated PGresult handle is passed to PQclear.

The following field codes are available:

PG_DIAG_SEVERITY

The severity; the field contents are ERROR, FATAL, or PANIC (in an error message), or WARNING, NOTICE, DEBUG, INFO, or LOG (in a notice message), or a localized translation of one of these. Always present.

PG_DIAG_SQLSTATE

The SQLSTATE code for the error. The SQLSTATE code identifies the type of error that has occurred; it can be used by front-end applications to perform specific operations (such as error handling) in response to a particular database error. For a list of the possible SQLSTATE codes, see Appendix A. This field is not localizable, and is always present.

PG_DIAG_MESSAGE_PRIMARY

The primary human-readable error message (typically one line). Always present.

PG_DIAG_MESSAGE_DETAIL

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

PG_DIAG_MESSAGE_HINT

Hint: an optional suggestion what to do about the problem. This is intended to differ from detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

PG_DIAG_STATEMENT_POSITION

A string containing a decimal integer indicating an error cursor position as an index into the original statement string. The first character has index 1, and positions are measured in characters not bytes.

PG_DIAG_INTERNAL_POSITION

This is defined the same as the PG_DIAG_STATEMENT_POSITION field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The PG_DIAG_INTERNAL_QUERY field will always appear when this field appears.

PG_DIAG_INTERNAL_QUERY

The text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

PG_DIAG_CONTEXT

An indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

PG_DIAG_SCHEMA_NAME

If the error was associated with a specific database object, the name of the schema containing that object, if any.

PG_DIAG_TABLE_NAME

If the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

PG_DIAG_COLUMN_NAME

If the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

PG_DIAG_DATATYPE_NAME

If the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

PG_DIAG_CONSTRAINT_NAME

If the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

PG_DIAG_SOURCE_FILE

The file name of the source-code location where the error was reported.

PG_DIAG_SOURCE_LINE

The line number of the source-code location where the error was reported.

PG_DIAG_SOURCE_FUNCTION

The name of the source-code function reporting the error.

> **Note:** The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Do not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, do not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

Errors generated internally by libpq will have severity and primary message, but typically no other fields. Errors returned by a pre-3.0-protocol server will include severity and primary message, and sometimes a detail message, but no other fields.

Note that error fields are only available from `PGresult` objects, not `PGconn` objects; there is no `PQerrorField` function.

`PQclear`

Frees the storage associated with a `PGresult`. Every command result should be freed via `PQclear` when it is no longer needed.

```
void PQclear(PGresult *res);
```

You can keep a `PGresult` object around for as long as you need it; it does not go away when you issue a new command, nor even if you close the connection. To get rid of it, you must call `PQclear`. Failure to do this will result in memory leaks in your application.

31.3.2. Retrieving Query Result Information

These functions are used to extract information from a `PGresult` object that represents a successful query result (that is, one that has status `PGRES_TUPLES_OK` or `PGRES_SINGLE_TUPLE`). They can also be used to extract information from a successful Describe operation: a Describe's result has all the same column information that actual execution of the query would provide, but it has zero rows. For objects with other status values, these functions will act as though the result has zero rows and zero columns.

`PQntuples`

Returns the number of rows (tuples) in the query result. Because it returns an integer result, large result sets might overflow the return value on 32-bit operating systems.

```
int PQntuples(const PGresult *res);
```

`PQnfields`

Returns the number of columns (fields) in each row of the query result.

```
int PQnfields(const PGresult *res);
```

PQfname

Returns the column name associated with the given column number. Column numbers start at 0. The caller should not free the result directly. It will be freed when the associated PGresult handle is passed to PQclear.

```
char *PQfname(const PGresult *res,
              int column_number);
```

NULL is returned if the column number is out of range.

PQfnumber

Returns the column number associated with the given column name.

```
int PQfnumber(const PGresult *res,
              const char *column_name);
```

-1 is returned if the given name does not match any column.

The given name is treated like an identifier in an SQL command, that is, it is downcased unless double-quoted. For example, given a query result generated from the SQL command:

```
SELECT 1 AS FOO, 2 AS "BAR";
```

we would have the results:

```
PQfname(res, 0)              foo
PQfname(res, 1)              BAR
PQfnumber(res, "FOO")        0
PQfnumber(res, "foo")        0
PQfnumber(res, "BAR")        -1
PQfnumber(res, "\"BAR\"")    1
```

PQftable

Returns the OID of the table from which the given column was fetched. Column numbers start at 0.

```
Oid PQftable(const PGresult *res,
             int column_number);
```

InvalidOid is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol. You can query the system table pg_class to determine exactly which table is referenced.

The type Oid and the constant InvalidOid will be defined when you include the libpq header file. They will both be some integer type.

PQftablecol

Returns the column number (within its table) of the column making up the specified query result column. Query-result column numbers start at 0, but table columns have nonzero numbers.

```
int PQftablecol(const PGresult *res,
                int column_number);
```

Zero is returned if the column number is out of range, or if the specified column is not a simple reference to a table column, or when using pre-3.0 protocol.

PQfformat

Returns the format code indicating the format of the given column. Column numbers start at 0.

```
int PQfformat(const PGresult *res,
              int column_number);
```

Format code zero indicates textual data representation, while format code one indicates binary representation. (Other codes are reserved for future definition.)

`PQftype`

Returns the data type associated with the given column number. The integer returned is the internal OID number of the type. Column numbers start at 0.

```
Oid PQftype(const PGresult *res,
            int column_number);
```

You can query the system table `pg_type` to obtain the names and properties of the various data types. The OIDs of the built-in data types are defined in the file `src/include/catalog/pg_type.h` in the source tree.

`PQfmod`

Returns the type modifier of the column associated with the given column number. Column numbers start at 0.

```
int PQfmod(const PGresult *res,
           int column_number);
```

The interpretation of modifier values is type-specific; they typically indicate precision or size limits. The value -1 is used to indicate "no information available". Most data types do not use modifiers, in which case the value is always -1.

`PQfsize`

Returns the size in bytes of the column associated with the given column number. Column numbers start at 0.

```
int PQfsize(const PGresult *res,
            int column_number);
```

`PQfsize` returns the space allocated for this column in a database row, in other words the size of the server's internal representation of the data type. (Accordingly, it is not really very useful to clients.) A negative value indicates the data type is variable-length.

`PQbinaryTuples`

Returns 1 if the `PGresult` contains binary data and 0 if it contains text data.

```
int PQbinaryTuples(const PGresult *res);
```

This function is deprecated (except for its use in connection with `COPY`), because it is possible for a single `PGresult` to contain text data in some columns and binary data in others. `PQfformat` is preferred. `PQbinaryTuples` returns 1 only if all columns of the result are binary (format 1).

`PQgetvalue`

Returns a single field value of one row of a `PGresult`. Row and column numbers start at 0. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

```
char *PQgetvalue(const PGresult *res,
                 int row_number,
                 int column_number);
```

For data in text format, the value returned by `PQgetvalue` is a null-terminated character string representation of the field value. For data in binary format, the value is in the binary representation determined by the data type's `typsend` and `typreceive` functions. (The value is actually followed by a zero byte in this case too, but that is not ordinarily useful, since the value is likely to contain embedded nulls.)

An empty string is returned if the field value is null. See PQgetisnull to distinguish null values from empty-string values.

The pointer returned by PQgetvalue points to storage that is part of the PGresult structure. One should not modify the data it points to, and one must explicitly copy the data into other storage if it is to be used past the lifetime of the PGresult structure itself.

PQgetisnull

Tests a field for a null value. Row and column numbers start at 0.

```
int PQgetisnull(const PGresult *res,
                int row_number,
                int column_number);
```

This function returns 1 if the field is null and 0 if it contains a non-null value. (Note that PQgetvalue will return an empty string, not a null pointer, for a null field.)

PQgetlength

Returns the actual length of a field value in bytes. Row and column numbers start at 0.

```
int PQgetlength(const PGresult *res,
                int row_number,
                int column_number);
```

This is the actual data length for the particular data value, that is, the size of the object pointed to by PQgetvalue. For text data format this is the same as strlen(). For binary format this is essential information. Note that one should *not* rely on PQfsize to obtain the actual data length.

PQnparams

Returns the number of parameters of a prepared statement.

```
int PQnparams(const PGresult *res);
```

This function is only useful when inspecting the result of PQdescribePrepared. For other types of queries it will return zero.

PQparamtype

Returns the data type of the indicated statement parameter. Parameter numbers start at 0.

```
Oid PQparamtype(const PGresult *res, int param_number);
```

This function is only useful when inspecting the result of PQdescribePrepared. For other types of queries it will return zero.

PQprint

Prints out all the rows and, optionally, the column names to the specified output stream.

```
void PQprint(FILE *fout,      /* output stream */
             const PGresult *res,
             const PQprintOpt *po);
typedef struct
{
    pqbool  header;      /* print output field headings and row count */
    pqbool  align;       /* fill align the fields */
    pqbool  standard;    /* old brain dead format */
    pqbool  html3;       /* output HTML tables */
    pqbool  expanded;    /* expand tables */
    pqbool  pager;       /* use pager for output if needed */
    char    *fieldSep;   /* field separator */
    char    *tableOpt;   /* attributes for HTML table element */
    char    *caption;    /* HTML table caption */
```

```
    char    **fieldName; /* null-terminated array of replacement field names */
} PQprintOpt;
```

This function was formerly used by psql to print query results, but this is no longer the case. Note that it assumes all the data is in text format.

31.3.3. Retrieving Other Result Information

These functions are used to extract other information from `PGresult` objects.

`PQcmdStatus`

Returns the command status tag from the SQL command that generated the `PGresult`.

```
char *PQcmdStatus(PGresult *res);
```

Commonly this is just the name of the command, but it might include additional data such as the number of rows processed. The caller should not free the result directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

`PQcmdTuples`

Returns the number of rows affected by the SQL command.

```
char *PQcmdTuples(PGresult *res);
```

This function returns a string containing the number of rows affected by the SQL statement that generated the `PGresult`. This function can only be used following the execution of a `SELECT`, `CREATE TABLE AS`, `INSERT`, `UPDATE`, `DELETE`, `MOVE`, `FETCH`, or `COPY` statement, or an `EXECUTE` of a prepared query that contains an `INSERT`, `UPDATE`, or `DELETE` statement. If the command that generated the `PGresult` was anything else, `PQcmdTuples` returns an empty string. The caller should not free the return value directly. It will be freed when the associated `PGresult` handle is passed to `PQclear`.

`PQoidValue`

Returns the OID of the inserted row, if the SQL command was an `INSERT` that inserted exactly one row into a table that has OIDs, or a `EXECUTE` of a prepared query containing a suitable `INSERT` statement. Otherwise, this function returns `InvalidOid`. This function will also return `InvalidOid` if the table affected by the `INSERT` statement does not contain OIDs.

```
Oid PQoidValue(const PGresult *res);
```

`PQoidStatus`

This function is deprecated in favor of `PQoidValue` and is not thread-safe. It returns a string with the OID of the inserted row, while `PQoidValue` returns the OID value.

```
char *PQoidStatus(const PGresult *res);
```

31.3.4. Escaping Strings for Inclusion in SQL Commands

`PQescapeLiteral`

```
char *PQescapeLiteral(PGconn *conn, const char *str, size_t length);
```

`PQescapeLiteral` escapes a string for use within an SQL command. This is useful when inserting data values as literal constants in SQL commands. Certain characters (such as quotes

and backslashes) must be escaped to prevent them from being interpreted specially by the SQL parser. PQescapeLiteral performs this operation.

PQescapeLiteral returns an escaped version of the str parameter in memory allocated with malloc(). This memory should be freed using PQfreemem() when the result is no longer needed. A terminating zero byte is not required, and should not be counted in length. (If a terminating zero byte is found before length bytes are processed, PQescapeLiteral stops at the zero; the behavior is thus rather like strncpy.) The return string has all special characters replaced so that they can be properly processed by the PostgreSQL string literal parser. A terminating zero byte is also added. The single quotes that must surround PostgreSQL string literals are included in the result string.

On error, PQescapeLiteral returns NULL and a suitable message is stored in the conn object.

> **Tip:** It is especially important to do proper escaping when handling strings that were received from an untrustworthy source. Otherwise there is a security risk: you are vulnerable to "SQL injection" attacks wherein unwanted SQL commands are fed to your database.

Note that it is not necessary nor correct to do escaping when a data value is passed as a separate parameter in PQexecParams or its sibling routines.

PQescapeIdentifier

```
char *PQescapeIdentifier(PGconn *conn, const char *str, size_t length);
```

PQescapeIdentifier escapes a string for use as an SQL identifier, such as a table, column, or function name. This is useful when a user-supplied identifier might contain special characters that would otherwise not be interpreted as part of the identifier by the SQL parser, or when the identifier might contain upper case characters whose case should be preserved.

PQescapeIdentifier returns a version of the str parameter escaped as an SQL identifier in memory allocated with malloc(). This memory must be freed using PQfreemem() when the result is no longer needed. A terminating zero byte is not required, and should not be counted in length. (If a terminating zero byte is found before length bytes are processed, PQescapeIdentifier stops at the zero; the behavior is thus rather like strncpy.) The return string has all special characters replaced so that it will be properly processed as an SQL identifier. A terminating zero byte is also added. The return string will also be surrounded by double quotes.

On error, PQescapeIdentifier returns NULL and a suitable message is stored in the conn object.

> **Tip:** As with string literals, to prevent SQL injection attacks, SQL identifiers must be escaped when they are received from an untrustworthy source.

PQescapeStringConn

```
size_t PQescapeStringConn(PGconn *conn,
                          char *to, const char *from, size_t length,
                          int *error);
```

PQescapeStringConn escapes string literals, much like PQescapeLiteral. Unlike PQescapeLiteral, the caller is responsible for providing an appropriately sized buffer. Furthermore, PQescapeStringConn does not generate the single quotes that must surround PostgreSQL string literals; they should be provided in the SQL command that the result is

inserted into. The parameter `from` points to the first character of the string that is to be escaped, and the `length` parameter gives the number of bytes in this string. A terminating zero byte is not required, and should not be counted in `length`. (If a terminating zero byte is found before `length` bytes are processed, `PQescapeStringConn` stops at the zero; the behavior is thus rather like `strncpy`.) `to` shall point to a buffer that is able to hold at least one more byte than twice the value of `length`, otherwise the behavior is undefined. Behavior is likewise undefined if the `to` and `from` strings overlap.

If the `error` parameter is not `NULL`, then `*error` is set to zero on success, nonzero on error. Presently the only possible error conditions involve invalid multibyte encoding in the source string. The output string is still generated on error, but it can be expected that the server will reject it as malformed. On error, a suitable message is stored in the `conn` object, whether or not `error` is `NULL`.

`PQescapeStringConn` returns the number of bytes written to `to`, not including the terminating zero byte.

`PQescapeString`

`PQescapeString` is an older, deprecated version of `PQescapeStringConn`.

```
size_t PQescapeString (char *to, const char *from, size_t length);
```

The only difference from `PQescapeStringConn` is that `PQescapeString` does not take `PGconn` or `error` parameters. Because of this, it cannot adjust its behavior depending on the connection properties (such as character encoding) and therefore *it might give the wrong results*. Also, it has no way to report error conditions.

`PQescapeString` can be used safely in client programs that work with only one PostgreSQL connection at a time (in this case it can find out what it needs to know "behind the scenes"). In other contexts it is a security hazard and should be avoided in favor of `PQescapeStringConn`.

`PQescapeByteaConn`

Escapes binary data for use within an SQL command with the type `bytea`. As with `PQescapeStringConn`, this is only used when inserting data directly into an SQL command string.

```
unsigned char *PQescapeByteaConn(PGconn *conn,
                                 const unsigned char *from,
                                 size_t from_length,
                                 size_t *to_length);
```

Certain byte values must be escaped when used as part of a `bytea` literal in an SQL statement. `PQescapeByteaConn` escapes bytes using either hex encoding or backslash escaping. See Section 8.4 for more information.

The `from` parameter points to the first byte of the string that is to be escaped, and the `from_length` parameter gives the number of bytes in this binary string. (A terminating zero byte is neither necessary nor counted.) The `to_length` parameter points to a variable that will hold the resultant escaped string length. This result string length includes the terminating zero byte of the result.

`PQescapeByteaConn` returns an escaped version of the `from` parameter binary string in memory allocated with `malloc()`. This memory should be freed using `PQfreemem()` when the result is no longer needed. The return string has all special characters replaced so that they can be properly processed by the PostgreSQL string literal parser, and the `bytea` input function. A terminating zero byte is also added. The single quotes that must surround PostgreSQL string literals are not part of the result string.

On error, a null pointer is returned, and a suitable error message is stored in the conn object. Currently, the only possible error is insufficient memory for the result string.

PQescapeBytea

PQescapeBytea is an older, deprecated version of PQescapeByteaConn.

```
unsigned char *PQescapeBytea(const unsigned char *from,
                             size_t from_length,
                             size_t *to_length);
```

The only difference from PQescapeByteaConn is that PQescapeBytea does not take a PGconn parameter. Because of this, PQescapeBytea can only be used safely in client programs that use a single PostgreSQL connection at a time (in this case it can find out what it needs to know "behind the scenes"). It *might give the wrong results* if used in programs that use multiple database connections (use PQescapeByteaConn in such cases).

PQunescapeBytea

Converts a string representation of binary data into binary data — the reverse of PQescapeBytea. This is needed when retrieving bytea data in text format, but not when retrieving it in binary format.

```
unsigned char *PQunescapeBytea(const unsigned char *from, size_t *to_length);
```

The from parameter points to a string such as might be returned by PQgetvalue when applied to a bytea column. PQunescapeBytea converts this string representation into its binary representation. It returns a pointer to a buffer allocated with malloc(), or NULL on error, and puts the size of the buffer in to_length. The result must be freed using PQfreemem when it is no longer needed.

This conversion is not exactly the inverse of PQescapeBytea, because the string is not expected to be "escaped" when received from PQgetvalue. In particular this means there is no need for string quoting considerations, and so no need for a PGconn parameter.

31.4. Asynchronous Command Processing

The PQexec function is adequate for submitting commands in normal, synchronous applications. It has a few deficiencies, however, that can be of importance to some users:

- PQexec waits for the command to be completed. The application might have other work to do (such as maintaining a user interface), in which case it won't want to block waiting for the response.
- Since the execution of the client application is suspended while it waits for the result, it is hard for the application to decide that it would like to try to cancel the ongoing command. (It can be done from a signal handler, but not otherwise.)
- PQexec can return only one PGresult structure. If the submitted command string contains multiple SQL commands, all but the last PGresult are discarded by PQexec.
- PQexec always collects the command's entire result, buffering it in a single PGresult. While this simplifies error-handling logic for the application, it can be impractical for results containing many rows.

Applications that do not like these limitations can instead use the underlying functions that PQexec is built from: PQsendQuery and PQgetResult. There are also PQsendQueryParams, PQsendPrepare, PQsendQueryPrepared, PQsendDescribePrepared, and PQsendDescribePortal, which can be used with PQgetResult to duplicate the functionality of PQexecParams, PQprepare, PQexecPrepared, PQdescribePrepared, and PQdescribePortal respectively.

PQsendQuery

Submits a command to the server without waiting for the result(s). 1 is returned if the command was successfully dispatched and 0 if not (in which case, use PQerrorMessage to get more information about the failure).

```
int PQsendQuery(PGconn *conn, const char *command);
```

After successfully calling PQsendQuery, call PQgetResult one or more times to obtain the results. PQsendQuery cannot be called again (on the same connection) until PQgetResult has returned a null pointer, indicating that the command is done.

PQsendQueryParams

Submits a command and separate parameters to the server without waiting for the result(s).

```
int PQsendQueryParams(PGconn *conn,
                      const char *command,
                      int nParams,
                      const Oid *paramTypes,
                      const char * const *paramValues,
                      const int *paramLengths,
                      const int *paramFormats,
                      int resultFormat);
```

This is equivalent to PQsendQuery except that query parameters can be specified separately from the query string. The function's parameters are handled identically to PQexecParams. Like PQexecParams, it will not work on 2.0-protocol connections, and it allows only one command in the query string.

PQsendPrepare

Sends a request to create a prepared statement with the given parameters, without waiting for completion.

```
int PQsendPrepare(PGconn *conn,
                  const char *stmtName,
                  const char *query,
                  int nParams,
                  const Oid *paramTypes);
```

This is an asynchronous version of PQprepare: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call PQgetResult to determine whether the server successfully created the prepared statement. The function's parameters are handled identically to PQprepare. Like PQprepare, it will not work on 2.0-protocol connections.

PQsendQueryPrepared

Sends a request to execute a prepared statement with given parameters, without waiting for the result(s).

```
int PQsendQueryPrepared(PGconn *conn,
                        const char *stmtName,
                        int nParams,
                        const char * const *paramValues,
                        const int *paramLengths,
                        const int *paramFormats,
```

```
                                int resultFormat);
```

This is similar to PQsendQueryParams, but the command to be executed is specified by naming a previously-prepared statement, instead of giving a query string. The function's parameters are handled identically to PQexecPrepared. Like PQexecPrepared, it will not work on 2.0-protocol connections.

PQsendDescribePrepared

Submits a request to obtain information about the specified prepared statement, without waiting for completion.

```
int PQsendDescribePrepared(PGconn *conn, const char *stmtName);
```

This is an asynchronous version of PQdescribePrepared: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call PQgetResult to obtain the results. The function's parameters are handled identically to PQdescribePrepared. Like PQdescribePrepared, it will not work on 2.0-protocol connections.

PQsendDescribePortal

Submits a request to obtain information about the specified portal, without waiting for completion.

```
int PQsendDescribePortal(PGconn *conn, const char *portalName);
```

This is an asynchronous version of PQdescribePortal: it returns 1 if it was able to dispatch the request, and 0 if not. After a successful call, call PQgetResult to obtain the results. The function's parameters are handled identically to PQdescribePortal. Like PQdescribePortal, it will not work on 2.0-protocol connections.

PQgetResult

Waits for the next result from a prior PQsendQuery, PQsendQueryParams, PQsendPrepare, PQsendQueryPrepared, PQsendDescribePrepared, or PQsendDescribePortal call, and returns it. A null pointer is returned when the command is complete and there will be no more results.

```
PGresult *PQgetResult(PGconn *conn);
```

PQgetResult must be called repeatedly until it returns a null pointer, indicating that the command is done. (If called when no command is active, PQgetResult will just return a null pointer at once.) Each non-null result from PQgetResult should be processed using the same PGresult accessor functions previously described. Don't forget to free each result object with PQclear when done with it. Note that PQgetResult will block only if a command is active and the necessary response data has not yet been read by PQconsumeInput.

> **Note:** Even when PQresultStatus indicates a fatal error, PQgetResult should be called until it returns a null pointer, to allow libpq to process the error information completely.

Using PQsendQuery and PQgetResult solves one of PQexec's problems: If a command string contains multiple SQL commands, the results of those commands can be obtained individually. (This allows a simple form of overlapped processing, by the way: the client can be handling the results of one command while the server is still working on later queries in the same command string.)

Another frequently-desired feature that can be obtained with PQsendQuery and PQgetResult is retrieving large query results a row at a time. This is discussed in Section 31.5.

By itself, calling PQgetResult will still cause the client to block until the server completes the next SQL command. This can be avoided by proper use of two more functions:

PQconsumeInput

If input is available from the server, consume it.

```
int PQconsumeInput(PGconn *conn);
```

PQconsumeInput normally returns 1 indicating "no error", but returns 0 if there was some kind of trouble (in which case PQerrorMessage can be consulted). Note that the result does not say whether any input data was actually collected. After calling PQconsumeInput, the application can check PQisBusy and/or PQnotifies to see if their state has changed.

PQconsumeInput can be called even if the application is not prepared to deal with a result or notification just yet. The function will read available data and save it in a buffer, thereby causing a select() read-ready indication to go away. The application can thus use PQconsumeInput to clear the select() condition immediately, and then examine the results at leisure.

PQisBusy

Returns 1 if a command is busy, that is, PQgetResult would block waiting for input. A 0 return indicates that PQgetResult can be called with assurance of not blocking.

```
int PQisBusy(PGconn *conn);
```

PQisBusy will not itself attempt to read data from the server; therefore PQconsumeInput must be invoked first, or the busy state will never end.

A typical application using these functions will have a main loop that uses select() or poll() to wait for all the conditions that it must respond to. One of the conditions will be input available from the server, which in terms of select() means readable data on the file descriptor identified by PQsocket. When the main loop detects input ready, it should call PQconsumeInput to read the input. It can then call PQisBusy, followed by PQgetResult if PQisBusy returns false (0). It can also call PQnotifies to detect NOTIFY messages (see Section 31.8).

A client that uses PQsendQuery/PQgetResult can also attempt to cancel a command that is still being processed by the server; see Section 31.6. But regardless of the return value of PQcancel, the application must continue with the normal result-reading sequence using PQgetResult. A successful cancellation will simply cause the command to terminate sooner than it would have otherwise.

By using the functions described above, it is possible to avoid blocking while waiting for input from the database server. However, it is still possible that the application will block waiting to send output to the server. This is relatively uncommon but can happen if very long SQL commands or data values are sent. (It is much more probable if the application sends data via COPY IN, however.) To prevent this possibility and achieve completely nonblocking database operation, the following additional functions can be used.

PQsetnonblocking

Sets the nonblocking status of the connection.

```
int PQsetnonblocking(PGconn *conn, int arg);
```

Sets the state of the connection to nonblocking if arg is 1, or blocking if arg is 0. Returns 0 if OK, -1 if error.

In the nonblocking state, calls to PQsendQuery, PQputline, PQputnbytes, and PQendcopy will not block but instead return an error if they need to be called again.

Note that PQexec does not honor nonblocking mode; if it is called, it will act in blocking fashion anyway.

PQisnonblocking

Returns the blocking status of the database connection.

```
int PQisnonblocking(const PGconn *conn);
```

Returns 1 if the connection is set to nonblocking mode and 0 if blocking.

PQflush

Attempts to flush any queued output data to the server. Returns 0 if successful (or if the send queue is empty), -1 if it failed for some reason, or 1 if it was unable to send all the data in the send queue yet (this case can only occur if the connection is nonblocking).

```
int PQflush(PGconn *conn);
```

After sending any command or data on a nonblocking connection, call PQflush. If it returns 1, wait for the socket to be write-ready and call it again; repeat until it returns 0. Once PQflush returns 0, wait for the socket to be read-ready and then read the response as described above.

31.5. Retrieving Query Results Row-By-Row

Ordinarily, libpq collects a SQL command's entire result and returns it to the application as a single PGresult. This can be unworkable for commands that return a large number of rows. For such cases, applications can use PQsendQuery and PQgetResult in *single-row mode*. In this mode, the result row(s) are returned to the application one at a time, as they are received from the server.

To enter single-row mode, call PQsetSingleRowMode immediately after a successful call of PQsendQuery (or a sibling function). This mode selection is effective only for the currently executing query. Then call PQgetResult repeatedly, until it returns null, as documented in Section 31.4. If the query returns any rows, they are returned as individual PGresult objects, which look like normal query results except for having status code PGRES_SINGLE_TUPLE instead of PGRES_TUPLES_OK. After the last row, or immediately if the query returns zero rows, a zero-row object with status PGRES_TUPLES_OK is returned; this is the signal that no more rows will arrive. (But note that it is still necessary to continue calling PQgetResult until it returns null.) All of these PGresult objects will contain the same row description data (column names, types, etc) that an ordinary PGresult object for the query would have. Each object should be freed with PQclear as usual.

PQsetSingleRowMode

Select single-row mode for the currently-executing query.

```
int PQsetSingleRowMode(PGconn *conn);
```

This function can only be called immediately after PQsendQuery or one of its sibling functions, before any other operation on the connection such as PQconsumeInput or PQgetResult. If called at the correct time, the function activates single-row mode for the current query and returns 1. Otherwise the mode stays unchanged and the function returns 0. In any case, the mode reverts to normal after completion of the current query.

Caution

While processing a query, the server may return some rows and then encounter an error, causing the query to be aborted. Ordinarily, libpq discards any such rows and reports only the error. But in single-row mode, those rows will have already been returned to the application. Hence, the application will see some `PGRES_SINGLE_TUPLE` `PGresult` objects followed by a `PGRES_FATAL_ERROR` object. For proper transactional behavior, the application must be designed to discard or undo whatever has been done with the previously-processed rows, if the query ultimately fails.

31.6. Canceling Queries in Progress

A client application can request cancellation of a command that is still being processed by the server, using the functions described in this section.

`PQgetCancel`

Creates a data structure containing the information needed to cancel a command issued through a particular database connection.

```
PGcancel *PQgetCancel(PGconn *conn);
```

`PQgetCancel` creates a `PGcancel` object given a `PGconn` connection object. It will return `NULL` if the given `conn` is `NULL` or an invalid connection. The `PGcancel` object is an opaque structure that is not meant to be accessed directly by the application; it can only be passed to `PQcancel` or `PQfreeCancel`.

`PQfreeCancel`

Frees a data structure created by `PQgetCancel`.

```
void PQfreeCancel(PGcancel *cancel);
```

`PQfreeCancel` frees a data object previously created by `PQgetCancel`.

`PQcancel`

Requests that the server abandon processing of the current command.

```
int PQcancel(PGcancel *cancel, char *errbuf, int errbufsize);
```

The return value is 1 if the cancel request was successfully dispatched and 0 if not. If not, `errbuf` is filled with an explanatory error message. `errbuf` must be a char array of size `errbufsize` (the recommended size is 256 bytes).

Successful dispatch is no guarantee that the request will have any effect, however. If the cancellation is effective, the current command will terminate early and return an error result. If the cancellation fails (say, because the server was already done processing the command), then there will be no visible result at all.

`PQcancel` can safely be invoked from a signal handler, if the `errbuf` is a local variable in the signal handler. The `PGcancel` object is read-only as far as `PQcancel` is concerned, so it can also be invoked from a thread that is separate from the one manipulating the `PGconn` object.

`PQrequestCancel`

`PQrequestCancel` is a deprecated variant of `PQcancel`.

```
int PQrequestCancel(PGconn *conn);
```

Requests that the server abandon processing of the current command. It operates directly on the `PGconn` object, and in case of failure stores the error message in the `PGconn` object (whence it can be retrieved by `PQerrorMessage`). Although the functionality is the same, this approach creates hazards for multiple-thread programs and signal handlers, since it is possible that overwriting the `PGconn`'s error message will mess up the operation currently in progress on the connection.

31.7. The Fast-Path Interface

PostgreSQL provides a fast-path interface to send simple function calls to the server.

> **Tip:** This interface is somewhat obsolete, as one can achieve similar performance and greater functionality by setting up a prepared statement to define the function call. Then, executing the statement with binary transmission of parameters and results substitutes for a fast-path function call.

The function `PQfn` requests execution of a server function via the fast-path interface:

```
PGresult *PQfn(PGconn *conn,
               int fnid,
               int *result_buf,
               int *result_len,
               int result_is_int,
               const PQArgBlock *args,
               int nargs);

typedef struct
{
    int len;
    int isint;
    union
    {
        int *ptr;
        int integer;
    } u;
} PQArgBlock;
```

The `fnid` argument is the OID of the function to be executed. `args` and `nargs` define the parameters to be passed to the function; they must match the declared function argument list. When the `isint` field of a parameter structure is true, the `u.integer` value is sent to the server as an integer of the indicated length (this must be 1, 2, or 4 bytes); proper byte-swapping occurs. When `isint` is false, the indicated number of bytes at `*u.ptr` are sent with no processing; the data must be in the format expected by the server for binary transmission of the function's argument data type. `result_buf` is the buffer in which to place the return value. The caller must have allocated sufficient space to store the return value. (There is no check!) The actual result length will be returned in the integer pointed

to by result_len. If a 1, 2, or 4-byte integer result is expected, set result_is_int to 1, otherwise set it to 0. Setting result_is_int to 1 causes libpq to byte-swap the value if necessary, so that it is delivered as a proper int value for the client machine. When result_is_int is 0, the binary-format byte string sent by the server is returned unmodified.

PQfn always returns a valid PGresult pointer. The result status should be checked before the result is used. The caller is responsible for freeing the PGresult with PQclear when it is no longer needed.

Note that it is not possible to handle null arguments, null results, nor set-valued results when using this interface.

31.8. Asynchronous Notification

PostgreSQL offers asynchronous notification via the LISTEN and NOTIFY commands. A client session registers its interest in a particular notification channel with the LISTEN command (and can stop listening with the UNLISTEN command). All sessions listening on a particular channel will be notified asynchronously when a NOTIFY command with that channel name is executed by any session. A "payload" string can be passed to communicate additional data to the listeners.

libpq applications submit LISTEN, UNLISTEN, and NOTIFY commands as ordinary SQL commands. The arrival of NOTIFY messages can subsequently be detected by calling PQnotifies.

The function PQnotifies returns the next notification from a list of unhandled notification messages received from the server. It returns a null pointer if there are no pending notifications. Once a notification is returned from PQnotifies, it is considered handled and will be removed from the list of notifications.

```
PGnotify *PQnotifies(PGconn *conn);

typedef struct pgNotify
{
    char *relname;              /* notification channel name */
    int  be_pid;                /* process ID of notifying server process */
    char *extra;                /* notification payload string */
} PGnotify;
```

After processing a PGnotify object returned by PQnotifies, be sure to free it with PQfreemem. It is sufficient to free the PGnotify pointer; the relname and extra fields do not represent separate allocations. (The names of these fields are historical; in particular, channel names need not have anything to do with relation names.)

Example 31-2 gives a sample program that illustrates the use of asynchronous notification.

PQnotifies does not actually read data from the server; it just returns messages previously absorbed by another libpq function. In prior releases of libpq, the only way to ensure timely receipt of NOTIFY messages was to constantly submit commands, even empty ones, and then check PQnotifies after each PQexec. While this still works, it is deprecated as a waste of processing power.

A better way to check for NOTIFY messages when you have no useful commands to execute is to call PQconsumeInput, then check PQnotifies. You can use select() to wait for data to arrive from the server, thereby using no CPU power unless there is something to do. (See PQsocket to obtain the file descriptor number to use with select().) Note that this will work OK whether you submit commands with PQsendQuery/PQgetResult or simply use PQexec. You should, however, remember to check PQnotifies after each PQgetResult or PQexec, to see if any notifications came in during the processing of the command.

31.9. Functions Associated with the COPY Command

The COPY command in PostgreSQL has options to read from or write to the network connection used by libpq. The functions described in this section allow applications to take advantage of this capability by supplying or consuming copied data.

The overall process is that the application first issues the SQL COPY command via PQexec or one of the equivalent functions. The response to this (if there is no error in the command) will be a PGresult object bearing a status code of PGRES_COPY_OUT or PGRES_COPY_IN (depending on the specified copy direction). The application should then use the functions of this section to receive or transmit data rows. When the data transfer is complete, another PGresult object is returned to indicate success or failure of the transfer. Its status will be PGRES_COMMAND_OK for success or PGRES_FATAL_ERROR if some problem was encountered. At this point further SQL commands can be issued via PQexec. (It is not possible to execute other SQL commands using the same connection while the COPY operation is in progress.)

If a COPY command is issued via PQexec in a string that could contain additional commands, the application must continue fetching results via PQgetResult after completing the COPY sequence. Only when PQgetResult returns NULL is it certain that the PQexec command string is done and it is safe to issue more commands.

The functions of this section should be executed only after obtaining a result status of PGRES_COPY_OUT or PGRES_COPY_IN from PQexec or PQgetResult.

A PGresult object bearing one of these status values carries some additional data about the COPY operation that is starting. This additional data is available using functions that are also used in connection with query results:

PQnfields

Returns the number of columns (fields) to be copied.

PQbinaryTuples

0 indicates the overall copy format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary. See COPY for more information.

PQfformat

Returns the format code (0 for text, 1 for binary) associated with each column of the copy operation. The per-column format codes will always be zero when the overall copy format is textual, but the binary format can support both text and binary columns. (However, as of the current implementation of COPY, only binary columns appear in a binary copy; so the per-column formats always match the overall format at present.)

Note: These additional data values are only available when using protocol 3.0. When using protocol 2.0, all these functions will return 0.

31.9.1. Functions for Sending COPY Data

These functions are used to send data during COPY FROM STDIN. They will fail if called when the connection is not in COPY_IN state.

PQputCopyData

Sends data to the server during COPY_IN state.

```
int PQputCopyData(PGconn *conn,
                  const char *buffer,
                  int nbytes);
```

Transmits the COPY data in the specified buffer, of length nbytes, to the server. The result is 1 if the data was sent, zero if it was not sent because the attempt would block (this case is only possible if the connection is in nonblocking mode), or -1 if an error occurred. (Use PQerrorMessage to retrieve details if the return value is -1. If the value is zero, wait for write-ready and try again.)

The application can divide the COPY data stream into buffer loads of any convenient size. Buffer-load boundaries have no semantic significance when sending. The contents of the data stream must match the data format expected by the COPY command; see COPY for details.

PQputCopyEnd

Sends end-of-data indication to the server during COPY_IN state.

```
int PQputCopyEnd(PGconn *conn,
                 const char *errormsg);
```

Ends the COPY_IN operation successfully if errormsg is NULL. If errormsg is not NULL then the COPY is forced to fail, with the string pointed to by errormsg used as the error message. (One should not assume that this exact error message will come back from the server, however, as the server might have already failed the COPY for its own reasons. Also note that the option to force failure does not work when using pre-3.0-protocol connections.)

The result is 1 if the termination data was sent, zero if it was not sent because the attempt would block (this case is only possible if the connection is in nonblocking mode), or -1 if an error occurred. (Use PQerrorMessage to retrieve details if the return value is -1. If the value is zero, wait for write-ready and try again.)

After successfully calling PQputCopyEnd, call PQgetResult to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

31.9.2. Functions for Receiving COPY Data

These functions are used to receive data during COPY TO STDOUT. They will fail if called when the connection is not in COPY_OUT state.

PQgetCopyData

Receives data from the server during COPY_OUT state.

```
int PQgetCopyData(PGconn *conn,
                  char **buffer,
                  int async);
```

Attempts to obtain another row of data from the server during a COPY. Data is always returned one data row at a time; if only a partial row is available, it is not returned. Successful return of a data row involves allocating a chunk of memory to hold the data. The buffer parameter must be non-NULL. *buffer is set to point to the allocated memory, or to NULL in cases where no buffer is returned. A non-NULL result buffer should be freed using PQfreemem when no longer needed.

When a row is successfully returned, the return value is the number of data bytes in the row (this will always be greater than zero). The returned string is always null-terminated, though this is probably only useful for textual COPY. A result of zero indicates that the COPY is still in progress, but no row is yet available (this is only possible when async is true). A result of -1 indicates that the COPY is done. A result of -2 indicates that an error occurred (consult PQerrorMessage for the reason).

When async is true (not zero), PQgetCopyData will not block waiting for input; it will return zero if the COPY is still in progress but no complete row is available. (In this case wait for read-ready and then call PQconsumeInput before calling PQgetCopyData again.) When async is false (zero), PQgetCopyData will block until data is available or the operation completes.

After PQgetCopyData returns -1, call PQgetResult to obtain the final result status of the COPY command. One can wait for this result to be available in the usual way. Then return to normal operation.

31.9.3. Obsolete Functions for COPY

These functions represent older methods of handling COPY. Although they still work, they are deprecated due to poor error handling, inconvenient methods of detecting end-of-data, and lack of support for binary or nonblocking transfers.

PQgetline

Reads a newline-terminated line of characters (transmitted by the server) into a buffer string of size length.

```
int PQgetline(PGconn *conn,
              char *buffer,
              int length);
```

This function copies up to length-1 characters into the buffer and converts the terminating newline into a zero byte. PQgetline returns EOF at the end of input, 0 if the entire line has been read, and 1 if the buffer is full but the terminating newline has not yet been read.

Note that the application must check to see if a new line consists of the two characters \., which indicates that the server has finished sending the results of the COPY command. If the application might receive lines that are more than length-1 characters long, care is needed to be sure it recognizes the \. line correctly (and does not, for example, mistake the end of a long data line for a terminator line).

PQgetlineAsync

Reads a row of COPY data (transmitted by the server) into a buffer without blocking.

```
int PQgetlineAsync(PGconn *conn,
                   char *buffer,
                   int bufsize);
```

This function is similar to PQgetline, but it can be used by applications that must read COPY data asynchronously, that is, without blocking. Having issued the COPY command and gotten a PGRES_COPY_OUT response, the application should call PQconsumeInput and PQgetlineAsync until the end-of-data signal is detected.

Unlike PQgetline, this function takes responsibility for detecting end-of-data.

On each call, PQgetlineAsync will return data if a complete data row is available in libpq's input buffer. Otherwise, no data is returned until the rest of the row arrives. The function returns -1 if the end-of-copy-data marker has been recognized, or 0 if no data is available, or a positive

number giving the number of bytes of data returned. If -1 is returned, the caller must next call PQendcopy, and then return to normal processing.

The data returned will not extend beyond a data-row boundary. If possible a whole row will be returned at one time. But if the buffer offered by the caller is too small to hold a row sent by the server, then a partial data row will be returned. With textual data this can be detected by testing whether the last returned byte is \n or not. (In a binary COPY, actual parsing of the COPY data format will be needed to make the equivalent determination.) The returned string is not null-terminated. (If you want to add a terminating null, be sure to pass a bufsize one smaller than the room actually available.)

PQputline

Sends a null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputline(PGconn *conn,
              const char *string);
```

The COPY data stream sent by a series of calls to PQputline has the same format as that returned by PQgetlineAsync, except that applications are not obliged to send exactly one data row per PQputline call; it is okay to send a partial line or multiple lines per call.

> **Note:** Before PostgreSQL protocol 3.0, it was necessary for the application to explicitly send the two characters \. as a final line to indicate to the server that it had finished sending COPY data. While this still works, it is deprecated and the special meaning of \. can be expected to be removed in a future release. It is sufficient to call PQendcopy after having sent the actual data.

PQputnbytes

Sends a non-null-terminated string to the server. Returns 0 if OK and EOF if unable to send the string.

```
int PQputnbytes(PGconn *conn,
                const char *buffer,
                int nbytes);
```

This is exactly like PQputline, except that the data buffer need not be null-terminated since the number of bytes to send is specified directly. Use this procedure when sending binary data.

PQendcopy

Synchronizes with the server.

```
int PQendcopy(PGconn *conn);
```

This function waits until the server has finished the copying. It should either be issued when the last string has been sent to the server using PQputline or when the last string has been received from the server using PGgetline. It must be issued or the server will get "out of sync" with the client. Upon return from this function, the server is ready to receive the next SQL command. The return value is 0 on successful completion, nonzero otherwise. (Use PQerrorMessage to retrieve details if the return value is nonzero.)

When using PQgetResult, the application should respond to a PGRES_COPY_OUT result by executing PQgetline repeatedly, followed by PQendcopy after the terminator line is seen. It should then return to the PQgetResult loop until PQgetResult returns a null pointer. Similarly a PGRES_COPY_IN result is processed by a series of PQputline calls followed by PQendcopy, then return to the PQgetResult loop. This arrangement will ensure that a COPY command embedded in a series of SQL commands will be executed correctly.

Older applications are likely to submit a COPY via PQexec and assume that the transaction is done after PQendcopy. This will work correctly only if the COPY is the only SQL command in the command string.

31.10. Control Functions

These functions control miscellaneous details of libpq's behavior.

PQclientEncoding

Returns the client encoding.

```
int PQclientEncoding(const PGconn *conn);
```

Note that it returns the encoding ID, not a symbolic string such as EUC_JP. If unsuccessful, it returns -1. To convert an encoding ID to an encoding name, you can use:

```
char *pg_encoding_to_char(int encoding_id);
```

PQsetClientEncoding

Sets the client encoding.

```
int PQsetClientEncoding(PGconn *conn, const char *encoding);
```

conn is a connection to the server, and *encoding* is the encoding you want to use. If the function successfully sets the encoding, it returns 0, otherwise -1. The current encoding for this connection can be determined by using PQclientEncoding.

PQsetErrorVerbosity

Determines the verbosity of messages returned by PQerrorMessage and PQresultErrorMessage.

```
typedef enum
{
    PQERRORS_TERSE,
    PQERRORS_DEFAULT,
    PQERRORS_VERBOSE
} PGVerbosity;

PGVerbosity PQsetErrorVerbosity(PGconn *conn, PGVerbosity verbosity);
```

PQsetErrorVerbosity sets the verbosity mode, returning the connection's previous setting. In *TERSE* mode, returned messages include severity, primary text, and position only; this will normally fit on a single line. The default mode produces messages that include the above plus any detail, hint, or context fields (these might span multiple lines). The *VERBOSE* mode includes all available fields. Changing the verbosity does not affect the messages available from already-existing PGresult objects, only subsequently-created ones.

PQtrace

Enables tracing of the client/server communication to a debugging file stream.

```
void PQtrace(PGconn *conn, FILE *stream);
```

> **Note:** On Windows, if the libpq library and an application are compiled with different flags, this function call will crash the application because the internal representation of the FILE pointers differ. Specifically, multithreaded/single-threaded, release/debug, and static/dynamic flags should be the same for the library and all applications using that library.

`PQuntrace`

Disables tracing started by `PQtrace`.

```
void PQuntrace(PGconn *conn);
```

31.11. Miscellaneous Functions

As always, there are some functions that just don't fit anywhere.

`PQfreemem`

Frees memory allocated by libpq.

```
void PQfreemem(void *ptr);
```

Frees memory allocated by libpq, particularly `PQescapeByteaConn`, `PQescapeBytea`, `PQunescapeBytea`, and `PQnotifies`. It is particularly important that this function, rather than `free()`, be used on Microsoft Windows. This is because allocating memory in a DLL and releasing it in the application works only if multithreaded/single-threaded, release/debug, and static/dynamic flags are the same for the DLL and the application. On non-Microsoft Windows platforms, this function is the same as the standard library function `free()`.

`PQconninfoFree`

Frees the data structures allocated by `PQconndefaults` or `PQconninfoParse`.

```
void PQconninfoFree(PQconninfoOption *connOptions);
```

A simple `PQfreemem` will not do for this, since the array contains references to subsidiary strings.

`PQencryptPassword`

Prepares the encrypted form of a PostgreSQL password.

```
char * PQencryptPassword(const char *passwd, const char *user);
```

This function is intended to be used by client applications that wish to send commands like `ALTER USER joe PASSWORD 'pwd'`. It is good practice not to send the original cleartext password in such a command, because it might be exposed in command logs, activity displays, and so on. Instead, use this function to convert the password to encrypted form before it is sent. The arguments are the cleartext password, and the SQL name of the user it is for. The return value is a string allocated by `malloc`, or `NULL` if out of memory. The caller can assume the string doesn't contain any special characters that would require escaping. Use `PQfreemem` to free the result when done with it.

`PQmakeEmptyPGresult`

Constructs an empty `PGresult` object with the given status.

```
PGresult *PQmakeEmptyPGresult(PGconn *conn, ExecStatusType status);
```

This is libpq's internal function to allocate and initialize an empty `PGresult` object. This function returns `NULL` if memory could not be allocated. It is exported because some applications find it useful to generate result objects (particularly objects with error status) themselves. If `conn` is not null and `status` indicates an error, the current error message of the specified connection is copied into the `PGresult`. Also, if `conn` is not null, any event procedures registered in the connection are copied into the `PGresult`. (They do not get `PGEVT_RESULTCREATE` calls, but see `PQfireResultCreateEvents`.) Note that `PQclear` should eventually be called on the object, just as with a `PGresult` returned by libpq itself.

PQfireResultCreateEvents

Fires a PGEVT_RESULTCREATE event (see Section 31.13) for each event procedure registered in the PGresult object. Returns non-zero for success, zero if any event procedure fails.

```
int PQfireResultCreateEvents(PGconn *conn, PGresult *res);
```

The conn argument is passed through to event procedures but not used directly. It can be NULL if the event procedures won't use it.

Event procedures that have already received a PGEVT_RESULTCREATE or PGEVT_RESULTCOPY event for this object are not fired again.

The main reason that this function is separate from PQmakeEmptyPGResult is that it is often appropriate to create a PGresult and fill it with data before invoking the event procedures.

PQcopyResult

Makes a copy of a PGresult object. The copy is not linked to the source result in any way and PQclear must be called when the copy is no longer needed. If the function fails, NULL is returned.

```
PGresult *PQcopyResult(const PGresult *src, int flags);
```

This is not intended to make an exact copy. The returned result is always put into PGRES_TUPLES_OK status, and does not copy any error message in the source. (It does copy the command status string, however.) The flags argument determines what else is copied. It is a bitwise OR of several flags. PG_COPYRES_ATTRS specifies copying the source result's attributes (column definitions). PG_COPYRES_TUPLES specifies copying the source result's tuples. (This implies copying the attributes, too.) PG_COPYRES_NOTICEHOOKS specifies copying the source result's notify hooks. PG_COPYRES_EVENTS specifies copying the source result's events. (But any instance data associated with the source is not copied.)

PQsetResultAttrs

Sets the attributes of a PGresult object.

```
int PQsetResultAttrs(PGresult *res, int numAttributes, PGresAttDesc *attDescs);
```

The provided attDescs are copied into the result. If the attDescs pointer is NULL or numAttributes is less than one, the request is ignored and the function succeeds. If res already contains attributes, the function will fail. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

PQsetvalue

Sets a tuple field value of a PGresult object.

```
int PQsetvalue(PGresult *res, int tup_num, int field_num, char *value, int len);
```

The function will automatically grow the result's internal tuples array as needed. However, the tup_num argument must be less than or equal to PQntuples, meaning this function can only grow the tuples array one tuple at a time. But any field of any existing tuple can be modified in any order. If a value at field_num already exists, it will be overwritten. If len is -1 or value is NULL, the field value will be set to an SQL null value. The value is copied into the result's private storage, thus is no longer needed after the function returns. If the function fails, the return value is zero. If the function succeeds, the return value is non-zero.

PQresultAlloc

Allocate subsidiary storage for a PGresult object.

```
void *PQresultAlloc(PGresult *res, size_t nBytes);
```

Any memory allocated with this function will be freed when `res` is cleared. If the function fails, the return value is `NULL`. The result is guaranteed to be adequately aligned for any type of data, just as for `malloc`.

`PQlibVersion`

Return the version of libpq that is being used.

```
int PQlibVersion(void);
```

The result of this function can be used to determine, at run time, if specific functionality is available in the currently loaded version of libpq. The function can be used, for example, to determine which connection options are available for `PQconnectdb` or if the `hex bytea` output added in PostgreSQL 9.0 is supported.

The number is formed by converting the major, minor, and revision numbers into two-decimal-digit numbers and appending them together. For example, version 9.1 will be returned as 90100, and version 9.1.2 will be returned as 90102 (leading zeroes are not shown).

> **Note:** This function appeared in PostgreSQL version 9.1, so it cannot be used to detect required functionality in earlier versions, since linking to it will create a link dependency on version 9.1.

31.12. Notice Processing

Notice and warning messages generated by the server are not returned by the query execution functions, since they do not imply failure of the query. Instead they are passed to a notice handling function, and execution continues normally after the handler returns. The default notice handling function prints the message on `stderr`, but the application can override this behavior by supplying its own handling function.

For historical reasons, there are two levels of notice handling, called the notice receiver and notice processor. The default behavior is for the notice receiver to format the notice and pass a string to the notice processor for printing. However, an application that chooses to provide its own notice receiver will typically ignore the notice processor layer and just do all the work in the notice receiver.

The function `PQsetNoticeReceiver` sets or examines the current notice receiver for a connection object. Similarly, `PQsetNoticeProcessor` sets or examines the current notice processor.

```
typedef void (*PQnoticeReceiver) (void *arg, const PGresult *res);

PQnoticeReceiver
PQsetNoticeReceiver(PGconn *conn,
                    PQnoticeReceiver proc,
                    void *arg);

typedef void (*PQnoticeProcessor) (void *arg, const char *message);

PQnoticeProcessor
PQsetNoticeProcessor(PGconn *conn,
                     PQnoticeProcessor proc,
                     void *arg);
```

Each of these functions returns the previous notice receiver or processor function pointer, and sets the new value. If you supply a null function pointer, no action is taken, but the current pointer is returned.

When a notice or warning message is received from the server, or generated internally by libpq, the notice receiver function is called. It is passed the message in the form of a `PGRES_NONFATAL_ERROR` `PGresult`. (This allows the receiver to extract individual fields using `PQresultErrorField`, or the complete preformatted message using `PQresultErrorMessage`.) The same void pointer passed to `PQsetNoticeReceiver` is also passed. (This pointer can be used to access application-specific state if needed.)

The default notice receiver simply extracts the message (using `PQresultErrorMessage`) and passes it to the notice processor.

The notice processor is responsible for handling a notice or warning message given in text form. It is passed the string text of the message (including a trailing newline), plus a void pointer that is the same one passed to `PQsetNoticeProcessor`. (This pointer can be used to access application-specific state if needed.)

The default notice processor is simply:

```
static void
defaultNoticeProcessor(void *arg, const char *message)
{
    fprintf(stderr, "%s", message);
}
```

Once you have set a notice receiver or processor, you should expect that that function could be called as long as either the `PGconn` object or `PGresult` objects made from it exist. At creation of a `PGresult`, the `PGconn`'s current notice handling pointers are copied into the `PGresult` for possible use by functions like `PQgetvalue`.

31.13. Event System

libpq's event system is designed to notify registered event handlers about interesting libpq events, such as the creation or destruction of `PGconn` and `PGresult` objects. A principal use case is that this allows applications to associate their own data with a `PGconn` or `PGresult` and ensure that that data is freed at an appropriate time.

Each registered event handler is associated with two pieces of data, known to libpq only as opaque `void *` pointers. There is a *passthrough* pointer that is provided by the application when the event handler is registered with a `PGconn`. The passthrough pointer never changes for the life of the `PGconn` and all `PGresult`s generated from it; so if used, it must point to long-lived data. In addition there is an *instance data* pointer, which starts out `NULL` in every `PGconn` and `PGresult`. This pointer can be manipulated using the `PQinstanceData`, `PQsetInstanceData`, `PQresultInstanceData` and `PQsetResultInstanceData` functions. Note that unlike the passthrough pointer, instance data of a `PGconn` is not automatically inherited by `PGresult`s created from it. libpq does not know what passthrough and instance data pointers point to (if anything) and will never attempt to free them — that is the responsibility of the event handler.

31.13.1. Event Types

The enum PGEventId names the types of events handled by the event system. All its values have names beginning with PGEVT. For each event type, there is a corresponding event info structure that carries the parameters passed to the event handlers. The event types are:

PGEVT_REGISTER

The register event occurs when PQregisterEventProc is called. It is the ideal time to initialize any instanceData an event procedure may need. Only one register event will be fired per event handler per connection. If the event procedure fails, the registration is aborted.

```
typedef struct
{
    PGconn *conn;
} PGEventRegister;
```

When a PGEVT_REGISTER event is received, the evtInfo pointer should be cast to a PGEventRegister *. This structure contains a PGconn that should be in the CONNECTION_OK status; guaranteed if one calls PQregisterEventProc right after obtaining a good PGconn. When returning a failure code, all cleanup must be performed as no PGEVT_CONNDESTROY event will be sent.

PGEVT_CONNRESET

The connection reset event is fired on completion of PQreset or PQresetPoll. In both cases, the event is only fired if the reset was successful. If the event procedure fails, the entire connection reset will fail; the PGconn is put into CONNECTION_BAD status and PQresetPoll will return PGRES_POLLING_FAILED.

```
typedef struct
{
    PGconn *conn;
} PGEventConnReset;
```

When a PGEVT_CONNRESET event is received, the evtInfo pointer should be cast to a PGEventConnReset *. Although the contained PGconn was just reset, all event data remains unchanged. This event should be used to reset/reload/requery any associated instanceData. Note that even if the event procedure fails to process PGEVT_CONNRESET, it will still receive a PGEVT_CONNDESTROY event when the connection is closed.

PGEVT_CONNDESTROY

The connection destroy event is fired in response to PQfinish. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```
typedef struct
{
    PGconn *conn;
} PGEventConnDestroy;
```

When a PGEVT_CONNDESTROY event is received, the evtInfo pointer should be cast to a PGEventConnDestroy *. This event is fired prior to PQfinish performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from PQfinish. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

PGEVT_RESULTCREATE

The result creation event is fired in response to any query execution function that generates a result, including PQgetResult. This event will only be fired after the result has been created successfully.

```
typedef struct
{
    PGconn *conn;
    PGresult *result;
} PGEventResultCreate;
```

When a PGEVT_RESULTCREATE event is received, the evtInfo pointer should be cast to a PGEventResultCreate *. The conn is the connection used to generate the result. This is the ideal place to initialize any instanceData that needs to be associated with the result. If the event procedure fails, the result will be cleared and the failure will be propagated. The event procedure must not try to PQclear the result object for itself. When returning a failure code, all cleanup must be performed as no PGEVT_RESULTDESTROY event will be sent.

PGEVT_RESULTCOPY

The result copy event is fired in response to PQcopyResult. This event will only be fired after the copy is complete. Only event procedures that have successfully handled the PGEVT_RESULTCREATE or PGEVT_RESULTCOPY event for the source result will receive PGEVT_RESULTCOPY events.

```
typedef struct
{
    const PGresult *src;
    PGresult *dest;
} PGEventResultCopy;
```

When a PGEVT_RESULTCOPY event is received, the evtInfo pointer should be cast to a PGEventResultCopy *. The src result is what was copied while the dest result is the copy destination. This event can be used to provide a deep copy of instanceData, since PQcopyResult cannot do that. If the event procedure fails, the entire copy operation will fail and the dest result will be cleared. When returning a failure code, all cleanup must be performed as no PGEVT_RESULTDESTROY event will be sent for the destination result.

PGEVT_RESULTDESTROY

The result destroy event is fired in response to a PQclear. It is the event procedure's responsibility to properly clean up its event data as libpq has no ability to manage this memory. Failure to clean up will lead to memory leaks.

```
typedef struct
{
    PGresult *result;
} PGEventResultDestroy;
```

When a PGEVT_RESULTDESTROY event is received, the evtInfo pointer should be cast to a PGEventResultDestroy *. This event is fired prior to PQclear performing any other cleanup. The return value of the event procedure is ignored since there is no way of indicating a failure from PQclear. Also, an event procedure failure should not abort the process of cleaning up unwanted memory.

31.13.2. Event Callback Procedure

`PGEventProc`

`PGEventProc` is a typedef for a pointer to an event procedure, that is, the user callback function that receives events from libpq. The signature of an event procedure must be

```
int eventproc(PGEventId evtId, void *evtInfo, void *passThrough)
```

The `evtId` parameter indicates which `PGEVT` event occurred. The `evtInfo` pointer must be cast to the appropriate structure type to obtain further information about the event. The `passThrough` parameter is the pointer provided to `PQregisterEventProc` when the event procedure was registered. The function should return a non-zero value if it succeeds and zero if it fails.

A particular event procedure can be registered only once in any `PGconn`. This is because the address of the procedure is used as a lookup key to identify the associated instance data.

> **Caution**
>
> On Windows, functions can have two different addresses: one visible from outside a DLL and another visible from inside the DLL. One should be careful that only one of these addresses is used with libpq's event-procedure functions, else confusion will result. The simplest rule for writing code that will work is to ensure that event procedures are declared `static`. If the procedure's address must be available outside its own source file, expose a separate function to return the address.

31.13.3. Event Support Functions

`PQregisterEventProc`

Registers an event callback procedure with libpq.

```
int PQregisterEventProc(PGconn *conn, PGEventProc proc,
                        const char *name, void *passThrough);
```

An event procedure must be registered once on each `PGconn` you want to receive events about. There is no limit, other than memory, on the number of event procedures that can be registered with a connection. The function returns a non-zero value if it succeeds and zero if it fails.

The `proc` argument will be called when a libpq event is fired. Its memory address is also used to lookup `instanceData`. The `name` argument is used to refer to the event procedure in error messages. This value cannot be `NULL` or a zero-length string. The name string is copied into the `PGconn`, so what is passed need not be long-lived. The `passThrough` pointer is passed to the `proc` whenever an event occurs. This argument can be `NULL`.

`PQsetInstanceData`

Sets the connection `conn`'s `instanceData` for procedure `proc` to `data`. This returns non-zero for success and zero for failure. (Failure is only possible if `proc` has not been properly registered in `conn`.)

```
int PQsetInstanceData(PGconn *conn, PGEventProc proc, void *data);
```

`PQinstanceData`

Returns the connection `conn`'s `instanceData` associated with procedure `proc`, or `NULL` if there is none.

```
void *PQinstanceData(const PGconn *conn, PGEventProc proc);
```

`PQresultSetInstanceData`

Sets the result's `instanceData` for `proc` to `data`. This returns non-zero for success and zero for failure. (Failure is only possible if `proc` has not been properly registered in the result.)

```
int PQresultSetInstanceData(PGresult *res, PGEventProc proc, void *data);
```

`PQresultInstanceData`

Returns the result's `instanceData` associated with `proc`, or `NULL` if there is none.

```
void *PQresultInstanceData(const PGresult *res, PGEventProc proc);
```

31.13.4. Event Example

Here is a skeleton example of managing private data associated with libpq connections and results.

```
/* required header for libpq events (note: includes libpq-fe.h) */
#include <libpq-events.h>

/* The instanceData */
typedef struct
{
    int n;
    char *str;
} mydata;

/* PGEventProc */
static int myEventProc(PGEventId evtId, void *evtInfo, void *passThrough);

int
main(void)
{
    mydata *data;
    PGresult *res;
    PGconn *conn = PQconnectdb("dbname = postgres");

    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
                PQerrorMessage(conn));
        PQfinish(conn);
        return 1;
    }

    /* called once on any connection that should receive events.
     * Sends a PGEVT_REGISTER to myEventProc.
     */
    if (!PQregisterEventProc(conn, myEventProc, "mydata_proc", NULL))
    {
        fprintf(stderr, "Cannot register PGEventProc\n");
        PQfinish(conn);
        return 1;
```

```
    }

    /* conn instanceData is available */
    data = PQinstanceData(conn, myEventProc);

    /* Sends a PGEVT_RESULTCREATE to myEventProc */
    res = PQexec(conn, "SELECT 1 + 1");

    /* result instanceData is available */
    data = PQresultInstanceData(res, myEventProc);

    /* If PG_COPYRES_EVENTS is used, sends a PGEVT_RESULTCOPY to myEventProc */
    res_copy = PQcopyResult(res, PG_COPYRES_TUPLES | PG_COPYRES_EVENTS);

    /* result instanceData is available if PG_COPYRES_EVENTS was
     * used during the PQcopyResult call.
     */
    data = PQresultInstanceData(res_copy, myEventProc);

    /* Both clears send a PGEVT_RESULTDESTROY to myEventProc */
    PQclear(res);
    PQclear(res_copy);

    /* Sends a PGEVT_CONNDESTROY to myEventProc */
    PQfinish(conn);

    return 0;
}

static int
myEventProc(PGEventId evtId, void *evtInfo, void *passThrough)
{
    switch (evtId)
    {
        case PGEVT_REGISTER:
        {
            PGEventRegister *e = (PGEventRegister *)evtInfo;
            mydata *data = get_mydata(e->conn);

            /* associate app specific data with connection */
            PQsetInstanceData(e->conn, myEventProc, data);
            break;
        }

        case PGEVT_CONNRESET:
        {
            PGEventConnReset *e = (PGEventConnReset *)evtInfo;
            mydata *data = PQinstanceData(e->conn, myEventProc);

            if (data)
              memset(data, 0, sizeof(mydata));
            break;
        }

        case PGEVT_CONNDESTROY:
        {
            PGEventConnDestroy *e = (PGEventConnDestroy *)evtInfo;
```

```
            mydata *data = PQinstanceData(e->conn, myEventProc);

            /* free instance data because the conn is being destroyed */
            if (data)
              free_mydata(data);
            break;
        }

        case PGEVT_RESULTCREATE:
        {
            PGEventResultCreate *e = (PGEventResultCreate *)evtInfo;
            mydata *conn_data = PQinstanceData(e->conn, myEventProc);
            mydata *res_data = dup_mydata(conn_data);

            /* associate app specific data with result (copy it from conn) */
            PQsetResultInstanceData(e->result, myEventProc, res_data);
            break;
        }

        case PGEVT_RESULTCOPY:
        {
            PGEventResultCopy *e = (PGEventResultCopy *)evtInfo;
            mydata *src_data = PQresultInstanceData(e->src, myEventProc);
            mydata *dest_data = dup_mydata(src_data);

            /* associate app specific data with result (copy it from a result) */
            PQsetResultInstanceData(e->dest, myEventProc, dest_data);
            break;
        }

        case PGEVT_RESULTDESTROY:
        {
            PGEventResultDestroy *e = (PGEventResultDestroy *)evtInfo;
            mydata *data = PQresultInstanceData(e->result, myEventProc);

            /* free instance data because the result is being destroyed */
            if (data)
              free_mydata(data);
            break;
        }

        /* unknown event ID, just return TRUE. */
        default:
            break;
    }

    return TRUE; /* event processing succeeded */
}
```

31.14. Environment Variables

The following environment variables can be used to select default connection parameter values, which will be used by `PQconnectdb`, `PQsetdbLogin` and `PQsetdb` if no value is directly specified by the calling code. These are useful to avoid hard-coding database connection information into simple client applications, for example.

- `PGHOST` behaves the same as the host connection parameter.
- `PGHOSTADDR` behaves the same as the hostaddr connection parameter. This can be set instead of or in addition to `PGHOST` to avoid DNS lookup overhead.
- `PGPORT` behaves the same as the port connection parameter.
- `PGDATABASE` behaves the same as the dbname connection parameter.
- `PGUSER` behaves the same as the user connection parameter.
- `PGPASSWORD` behaves the same as the password connection parameter. Use of this environment variable is not recommended for security reasons, as some operating systems allow non-root users to see process environment variables via ps; instead consider using the `~/.pgpass` file (see Section 31.15).
- `PGPASSFILE` specifies the name of the password file to use for lookups. If not set, it defaults to `~/.pgpass` (see Section 31.15).
- `PGSERVICE` behaves the same as the service connection parameter.
- `PGSERVICEFILE` specifies the name of the per-user connection service file. If not set, it defaults to `~/.pg_service.conf` (see Section 31.16).
- `PGREALM` sets the Kerberos realm to use with PostgreSQL, if it is different from the local realm. If `PGREALM` is set, libpq applications will attempt authentication with servers for this realm and use separate ticket files to avoid conflicts with local ticket files. This environment variable is only used if GSSAPI authentication is selected by the server.
- `PGOPTIONS` behaves the same as the options connection parameter.
- `PGAPPNAME` behaves the same as the application_name connection parameter.
- `PGSSLMODE` behaves the same as the sslmode connection parameter.
- `PGREQUIRESSL` behaves the same as the requiressl connection parameter.
- `PGSSLCOMPRESSION` behaves the same as the sslcompression connection parameter.
- `PGSSLCERT` behaves the same as the sslcert connection parameter.
- `PGSSLKEY` behaves the same as the sslkey connection parameter.
- `PGSSLROOTCERT` behaves the same as the sslrootcert connection parameter.
- `PGSSLCRL` behaves the same as the sslcrl connection parameter.
- `PGREQUIREPEER` behaves the same as the requirepeer connection parameter.
- `PGKRBSRVNAME` behaves the same as the krbsrvname connection parameter.
- `PGGSSLIB` behaves the same as the gsslib connection parameter.
- `PGCONNECT_TIMEOUT` behaves the same as the connect_timeout connection parameter.
- `PGCLIENTENCODING` behaves the same as the client_encoding connection parameter.

The following environment variables can be used to specify default behavior for each PostgreSQL session. (See also the ALTER ROLE and ALTER DATABASE commands for ways to set default behavior on a per-user or per-database basis.)

- `PGDATESTYLE` sets the default style of date/time representation. (Equivalent to `SET datestyle TO ...`.)
- `PGTZ` sets the default time zone. (Equivalent to `SET timezone TO ...`.)
- `PGGEQO` sets the default mode for the genetic query optimizer. (Equivalent to `SET geqo TO ...`.)

Refer to the SQL command SET for information on correct values for these environment variables.

The following environment variables determine internal behavior of libpq; they override compiled-in defaults.

- `PGSYSCONFDIR` sets the directory containing the `pg_service.conf` file and in a future version possibly other system-wide configuration files.
- `PGLOCALEDIR` sets the directory containing the `locale` files for message internationalization.

31.15. The Password File

The file `.pgpass` in a user's home directory or the file referenced by `PGPASSFILE` can contain passwords to be used if the connection requires a password (and no password has been specified otherwise). On Microsoft Windows the file is named `%APPDATA%\postgresql\pgpass.conf` (where `%APPDATA%` refers to the Application Data subdirectory in the user's profile).

This file should contain lines of the following format:

hostname:*port*:*database*:*username*:*password*

(You can add a reminder comment to the file by copying the line above and preceding it with `#`.) Each of the first four fields can be a literal value, or `*`, which matches anything. The password field from the first line that matches the current connection parameters will be used. (Therefore, put more-specific entries first when you are using wildcards.) If an entry needs to contain `:` or `\`, escape this character with `\`. A host name of `localhost` matches both TCP (host name `localhost`) and Unix domain socket (`pghost` empty or the default socket directory) connections coming from the local machine. In a standby server, a database name of `replication` matches streaming replication connections made to the master server. The `database` field is of limited usefulness because users have the same password for all databases in the same cluster.

On Unix systems, the permissions on `.pgpass` must disallow any access to world or group; achieve this by the command `chmod 0600 ~/.pgpass`. If the permissions are less strict than this, the file will be ignored. On Microsoft Windows, it is assumed that the file is stored in a directory that is secure, so no special permissions check is made.

31.16. The Connection Service File

The connection service file allows libpq connection parameters to be associated with a single service name. That service name can then be specified by a libpq connection, and the associated settings will

be used. This allows connection parameters to be modified without requiring a recompile of the libpq application. The service name can also be specified using the `PGSERVICE` environment variable.

The connection service file can be a per-user service file at `~/.pg_service.conf` or the location specified by the environment variable `PGSERVICEFILE`, or it can be a system-wide file at `` `pg_config --sysconfdir`/pg_service.conf `` or in the directory specified by the environment variable `PGSYSCONFDIR`. If service definitions with the same name exist in the user and the system file, the user file takes precedence.

The file uses an "INI file" format where the section name is the service name and the parameters are connection parameters; see Section 31.1.2 for a list. For example:

```
# comment
[mydb]
host=somehost
port=5433
user=admin
```

An example file is provided at `share/pg_service.conf.sample`.

31.17. LDAP Lookup of Connection Parameters

If libpq has been compiled with LDAP support (option `--with-ldap` for `configure`) it is possible to retrieve connection options like `host` or `dbname` via LDAP from a central server. The advantage is that if the connection parameters for a database change, the connection information doesn't have to be updated on all client machines.

LDAP connection parameter lookup uses the connection service file `pg_service.conf` (see Section 31.16). A line in a `pg_service.conf` stanza that starts with `ldap://` will be recognized as an LDAP URL and an LDAP query will be performed. The result must be a list of `keyword = value` pairs which will be used to set connection options. The URL must conform to RFC 1959 and be of the form

```
ldap://[hostname[:port]]/search_base?attribute?search_scope?filter
```

where *`hostname`* defaults to `localhost` and *`port`* defaults to 389.

Processing of `pg_service.conf` is terminated after a successful LDAP lookup, but is continued if the LDAP server cannot be contacted. This is to provide a fallback with further LDAP URL lines that point to different LDAP servers, classical `keyword = value` pairs, or default connection options. If you would rather get an error message in this case, add a syntactically incorrect line after the LDAP URL.

A sample LDAP entry that has been created with the LDIF file

```
version:1
dn:cn=mydatabase,dc=mycompany,dc=com
changetype:add
objectclass:top
objectclass:device
cn:mydatabase
description:host=dbserver.mycompany.com
description:port=5439
description:dbname=mydb
description:user=mydb_user
description:sslmode=require
```

might be queried with the following LDAP URL:

```
ldap://ldap.mycompany.com/dc=mycompany,dc=com?description?one?(cn=mydatabase)
```

You can also mix regular service file entries with LDAP lookups. A complete example for a stanza in `pg_service.conf` would be:

```
# only host and port are stored in LDAP, specify dbname and user explicitly
[customerdb]
dbname=customer
user=appuser
ldap://ldap.acme.com/cn=dbserver,cn=hosts?pgconnectinfo?base?(objectclass=*)
```

31.18. SSL Support

PostgreSQL has native support for using SSL connections to encrypt client/server communications for increased security. See Section 17.9 for details about the server-side SSL functionality.

libpq reads the system-wide OpenSSL configuration file. By default, this file is named `openssl.cnf` and is located in the directory reported by `openssl version -d`. This default can be overridden by setting environment variable `OPENSSL_CONF` to the name of the desired configuration file.

31.18.1. Client Verification of Server Certificates

By default, PostgreSQL will not perform any verification of the server certificate. This means that it is possible to spoof the server identity (for example by modifying a DNS record or by taking over the server IP address) without the client knowing. In order to prevent spoofing, SSL certificate verification must be used.

If the parameter `sslmode` is set to `verify-ca`, libpq will verify that the server is trustworthy by checking the certificate chain up to a trusted certificate authority (CA). If `sslmode` is set to `verify-full`, libpq will *also* verify that the server host name matches its certificate. The SSL connection will fail if the server certificate cannot be verified. `verify-full` is recommended in most security-sensitive environments.

In `verify-full` mode, the `cn` (Common Name) attribute of the certificate is matched against the host name. If the `cn` attribute starts with an asterisk (`*`), it will be treated as a wildcard, and will match all characters *except* a dot (`.`). This means the certificate will not match subdomains. If the connection is made using an IP address instead of a host name, the IP address will be matched (without doing any DNS lookups).

To allow server certificate verification, the certificate(s) of one or more trusted CAs must be placed in the file `~/.postgresql/root.crt` in the user's home directory. If intermediate CAs appear in `root.crt`, the file must also contain certificate chains to their root CAs. (On Microsoft Windows the file is named `%APPDATA%\postgresql\root.crt`.)

Certificate Revocation List (CRL) entries are also checked if the file `~/.postgresql/root.crl` exists (`%APPDATA%\postgresql\root.crl` on Microsoft Windows).

The location of the root certificate file and the CRL can be changed by setting the connection parameters `sslrootcert` and `sslcrl` or the environment variables `PGSSLROOTCERT` and `PGSSLCRL`.

Note: For backwards compatibility with earlier versions of PostgreSQL, if a root CA file exists, the behavior of `sslmode=require` will be the same as that of `verify-ca`, meaning the server certificate is validated against the CA. Relying on this behavior is discouraged, and applications that need certificate validation should always use `verify-ca` or `verify-full`.

31.18.2. Client Certificates

If the server requests a trusted client certificate, libpq will send the certificate stored in file `~/.postgresql/postgresql.crt` in the user's home directory. The certificate must be signed by one of the certificate authorities (CA) trusted by the server. A matching private key file `~/.postgresql/postgresql.key` must also be present. The private key file must not allow any access to world or group; achieve this by the command `chmod 0600 ~/.postgresql/postgresql.key`. On Microsoft Windows these files are named `%APPDATA%\postgresql\postgresql.crt` and `%APPDATA%\postgresql\postgresql.key`, and there is no special permissions check since the directory is presumed secure. The location of the certificate and key files can be overridden by the connection parameters `sslcert` and `sslkey` or the environment variables `PGSSLCERT` and `PGSSLKEY`.

In some cases, the client certificate might be signed by an "intermediate" certificate authority, rather than one that is directly trusted by the server. To use such a certificate, append the certificate of the signing authority to the `postgresql.crt` file, then its parent authority's certificate, and so on up to a certificate authority, "root" or "intermediate", that is trusted by the server, i.e. signed by a certificate in the server's `root.crt` file.

Note that the client's `~/.postgresql/root.crt` lists the top-level CAs that are considered trusted for signing server certificates. In principle it need not list the CA that signed the client's certificate, though in most cases that CA would also be trusted for server certificates.

31.18.3. Protection Provided in Different Modes

The different values for the `sslmode` parameter provide different levels of protection. SSL can provide protection against three types of attacks:

Eavesdropping

If a third party can examine the network traffic between the client and the server, it can read both connection information (including the user name and password) and the data that is passed. SSL uses encryption to prevent this.

Man in the middle (MITM)

If a third party can modify the data while passing between the client and server, it can pretend to be the server and therefore see and modify data *even if it is encrypted*. The third party can then forward the connection information and data to the original server, making it impossible to detect this attack. Common vectors to do this include DNS poisoning and address hijacking, whereby the client is directed to a different server than intended. There are also several other attack methods that can accomplish this. SSL uses certificate verification to prevent this, by authenticating the server to the client.

Impersonation

> If a third party can pretend to be an authorized client, it can simply access data it should not have access to. Typically this can happen through insecure password management. SSL uses client certificates to prevent this, by making sure that only holders of valid certificates can access the server.

For a connection to be known secure, SSL usage must be configured on *both the client and the server* before the connection is made. If it is only configured on the server, the client may end up sending sensitive information (e.g. passwords) before it knows that the server requires high security. In libpq, secure connections can be ensured by setting the `sslmode` parameter to `verify-full` or `verify-ca`, and providing the system with a root certificate to verify against. This is analogous to using an `https` URL for encrypted web browsing.

Once the server has been authenticated, the client can pass sensitive data. This means that up until this point, the client does not need to know if certificates will be used for authentication, making it safe to specify that only in the server configuration.

All SSL options carry overhead in the form of encryption and key-exchange, so there is a tradeoff that has to be made between performance and security. Table 31-1 illustrates the risks the different `sslmode` values protect against, and what statement they make about security and overhead.

Table 31-1. SSL Mode Descriptions

`sslmode`	Eavesdropping protection	MITM protection	Statement
`disable`	No	No	I don't care about security, and I don't want to pay the overhead of encryption.
`allow`	Maybe	No	I don't care about security, but I will pay the overhead of encryption if the server insists on it.
`prefer`	Maybe	No	I don't care about encryption, but I wish to pay the overhead of encryption if the server supports it.
`require`	Yes	No	I want my data to be encrypted, and I accept the overhead. I trust that the network will make sure I always connect to the server I want.

sslmode	Eavesdropping protection	MITM protection	Statement
verify-ca	Yes	Depends on CA-policy	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server that I trust.
verify-full	Yes	Yes	I want my data encrypted, and I accept the overhead. I want to be sure that I connect to a server I trust, and that it's the one I specify.

The difference between verify-ca and verify-full depends on the policy of the root CA. If a public CA is used, verify-ca allows connections to a server that *somebody else* may have registered with the CA. In this case, verify-full should always be used. If a local CA is used, or even a self-signed certificate, using verify-ca often provides enough protection.

The default value for sslmode is prefer. As is shown in the table, this makes no sense from a security point of view, and it only promises performance overhead if possible. It is only provided as the default for backward compatibility, and is not recommended in secure deployments.

31.18.4. SSL Client File Usage

Table 31-2 summarizes the files that are relevant to the SSL setup on the client.

Table 31-2. Libpq/Client SSL File Usage

File	Contents	Effect
~/.postgresql/postgresql.crt	client certificate	requested by server
~/.postgresql/postgresql.key	client private key	proves client certificate sent by owner; does not indicate certificate owner is trustworthy
~/.postgresql/root.crt	trusted certificate authorities	checks that server certificate is signed by a trusted certificate authority
~/.postgresql/root.crl	certificates revoked by certificate authorities	server certificate must not be on this list

31.18.5. SSL Library Initialization

If your application initializes libssl and/or libcrypto libraries and libpq is built with SSL support, you should call PQinitOpenSSL to tell libpq that the libssl and/or libcrypto libraries have been initialized by your application, so that libpq will not also initialize those libraries. See http://h71000.www7.hp.com/doc/83final/BA554_90007/ch04.html for details on the SSL API.

`PQinitOpenSSL`

Allows applications to select which security libraries to initialize.

```
void PQinitOpenSSL(int do_ssl, int do_crypto);
```

When `do_ssl` is non-zero, libpq will initialize the OpenSSL library before first opening a database connection. When `do_crypto` is non-zero, the `libcrypto` library will be initialized. By default (if `PQinitOpenSSL` is not called), both libraries are initialized. When SSL support is not compiled in, this function is present but does nothing.

If your application uses and initializes either OpenSSL or its underlying `libcrypto` library, you *must* call this function with zeroes for the appropriate parameter(s) before first opening a database connection. Also be sure that you have done that initialization before opening a database connection.

`PQinitSSL`

Allows applications to select which security libraries to initialize.

```
void PQinitSSL(int do_ssl);
```

This function is equivalent to `PQinitOpenSSL(do_ssl, do_ssl)`. It is sufficient for applications that initialize both or neither of OpenSSL and `libcrypto`.

`PQinitSSL` has been present since PostgreSQL 8.0, while `PQinitOpenSSL` was added in PostgreSQL 8.4, so `PQinitSSL` might be preferable for applications that need to work with older versions of libpq.

31.19. Behavior in Threaded Programs

libpq is reentrant and thread-safe by default. You might need to use special compiler command-line options when you compile your application code. Refer to your system's documentation for information about how to build thread-enabled applications, or look in `src/Makefile.global` for `PTHREAD_CFLAGS` and `PTHREAD_LIBS`. This function allows the querying of libpq's thread-safe status:

`PQisthreadsafe`

Returns the thread safety status of the libpq library.

```
int PQisthreadsafe();
```

Returns 1 if the libpq is thread-safe and 0 if it is not.

One thread restriction is that no two threads attempt to manipulate the same `PGconn` object at the same time. In particular, you cannot issue concurrent commands from different threads through the same connection object. (If you need to run concurrent commands, use multiple connections.)

`PGresult` objects are normally read-only after creation, and so can be passed around freely between threads. However, if you use any of the `PGresult`-modifying functions described in Section 31.11 or Section 31.13, it's up to you to avoid concurrent operations on the same `PGresult`, too.

The deprecated functions `PQrequestCancel` and `PQoidStatus` are not thread-safe and should not be used in multithread programs. `PQrequestCancel` can be replaced by `PQcancel`. `PQoidStatus` can be replaced by `PQoidValue`.

If you are using Kerberos inside your application (in addition to inside libpq), you will need to do locking around Kerberos calls because Kerberos functions are not thread-safe. See function `PQregisterThreadLock` in the libpq source code for a way to do cooperative locking between libpq and your application.

If you experience problems with threaded applications, run the program in `src/tools/thread` to see if your platform has thread-unsafe functions. This program is run by `configure`, but for binary distributions your library might not match the library used to build the binaries.

31.20. Building libpq Programs

To build (i.e., compile and link) a program using libpq you need to do all of the following things:

- Include the `libpq-fe.h` header file:

  ```
  #include <libpq-fe.h>
  ```

  If you failed to do that then you will normally get error messages from your compiler similar to:

  ```
  foo.c: In function 'main':
  foo.c:34: 'PGconn' undeclared (first use in this function)
  foo.c:35: 'PGresult' undeclared (first use in this function)
  foo.c:54: 'CONNECTION_BAD' undeclared (first use in this function)
  foo.c:68: 'PGRES_COMMAND_OK' undeclared (first use in this function)
  foo.c:95: 'PGRES_TUPLES_OK' undeclared (first use in this function)
  ```

- Point your compiler to the directory where the PostgreSQL header files were installed, by supplying the `-I`*directory* option to your compiler. (In some cases the compiler will look into the directory in question by default, so you can omit this option.) For instance, your compile command line could look like:

  ```
  cc -c -I/usr/local/pgsql/include testprog.c
  ```

  If you are using makefiles then add the option to the `CPPFLAGS` variable:

  ```
  CPPFLAGS += -I/usr/local/pgsql/include
  ```

  If there is any chance that your program might be compiled by other users then you should not hardcode the directory location like that. Instead, you can run the utility `pg_config` to find out where the header files are on the local system:

  ```
  $ pg_config --includedir
  /usr/local/include
  ```

  If you have `pkg-config` installed, you can run instead:

  ```
  $ pkg-config --cflags libpq
  -I/usr/local/include
  ```

  Note that this will already include the `-I` in front of the path.

  Failure to specify the correct option to the compiler will result in an error message such as:

  ```
  testlibpq.c:8:22: libpq-fe.h: No such file or directory
  ```

- When linking the final program, specify the option `-lpq` so that the libpq library gets pulled in, as well as the option `-L`*directory* to point the compiler to the directory where the libpq library resides. (Again, the compiler will search some directories by default.) For maximum portability, put the `-L` option before the `-lpq` option. For example:

  ```
  cc -o testprog testprog1.o testprog2.o -L/usr/local/pgsql/lib -lpq
  ```

You can find out the library directory using `pg_config` as well:

```
$ pg_config --libdir
/usr/local/pgsql/lib
```

Or again use `pkg-config`:

```
$ pkg-config --libs libpq
-L/usr/local/pgsql/lib -lpq
```

Note again that this prints the full options, not only the path.

Error messages that point to problems in this area could look like the following:

```
testlibpq.o: In function 'main':
testlibpq.o(.text+0x60): undefined reference to 'PQsetdbLogin'
testlibpq.o(.text+0x71): undefined reference to 'PQstatus'
testlibpq.o(.text+0xa4): undefined reference to 'PQerrorMessage'
```

This means you forgot `-lpq`.

```
/usr/bin/ld: cannot find -lpq
```

This means you forgot the `-L` option or did not specify the right directory.

31.21. Example Programs

These examples and others can be found in the directory `src/test/examples` in the source code distribution.

Example 31-1. libpq Example Program 1

```
/*
 * testlibpq.c
 *
 *      Test the C version of libpq, the PostgreSQL frontend library.
 */
#include <stdio.h>
#include <stdlib.h>
#include <libpq-fe.h>

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    int         nFields;
    int         i,
                j;

    /*
```

```
 * If the user supplies a parameter on the command line, use it as the
 * conninfo string; otherwise default to setting dbname=postgres and using
 * environment variables or defaults for all other connection parameters.
 */
if (argc > 1)
    conninfo = argv[1];
else
    conninfo = "dbname = postgres";

/* Make a connection to the database */
conn = PQconnectdb(conninfo);

/* Check to see that the backend connection was successfully made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/*
 * Our test case here involves using a cursor, for which we must be inside
 * a transaction block.  We could do the whole thing with a single
 * PQexec() of "select * from pg_database", but that's too trivial to make
 * a good example.
 */

/* Start a transaction block */
res = PQexec(conn, "BEGIN");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "BEGIN command failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}

/*
 * Should PQclear PGresult whenever it is no longer needed to avoid memory
 * leaks
 */
PQclear(res);

/*
 * Fetch rows from pg_database, the system catalog of databases
 */
res = PQexec(conn, "DECLARE myportal CURSOR FOR select * from pg_database");
if (PQresultStatus(res) != PGRES_COMMAND_OK)
{
    fprintf(stderr, "DECLARE CURSOR failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
PQclear(res);

res = PQexec(conn, "FETCH ALL in myportal");
if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
```

```
        fprintf(stderr, "FETCH ALL failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    /* first, print out the attribute names */
    nFields = PQnfields(res);
    for (i = 0; i < nFields; i++)
        printf("%-15s", PQfname(res, i));
    printf("\n\n");

    /* next, print out the rows */
    for (i = 0; i < PQntuples(res); i++)
    {
        for (j = 0; j < nFields; j++)
            printf("%-15s", PQgetvalue(res, i, j));
        printf("\n");
    }

    PQclear(res);

    /* close the portal ... we don't bother to check for errors ... */
    res = PQexec(conn, "CLOSE myportal");
    PQclear(res);

    /* end the transaction */
    res = PQexec(conn, "END");
    PQclear(res);

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}
```

Example 31-2. libpq Example Program 2

```
/*
 * testlibpq2.c
 *      Test of the asynchronous notification interface
 *
 * Start this program, then from psql in another window do
 *   NOTIFY TBL2;
 * Repeat four times to get this program to exit.
 *
 * Or, if you want to get fancy, try this:
 * populate a database with the following commands
 * (provided in src/test/examples/testlibpq2.sql):
 *
 *   CREATE TABLE TBL1 (i int4);
 *
 *   CREATE TABLE TBL2 (i int4);
 *
 *   CREATE RULE r1 AS ON INSERT TO TBL1 DO
 *     (INSERT INTO TBL2 VALUES (new.i); NOTIFY TBL2);
 *
 * and do this four times:
```

```
 *
 *   INSERT INTO TBL1 VALUES (10);
 */

#ifdef WIN32
#include <windows.h>
#endif
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <errno.h>
#include <sys/time.h>
#include <sys/types.h>
#include "libpq-fe.h"

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    const char *conninfo;
    PGconn     *conn;
    PGresult   *res;
    PGnotify   *notify;
    int         nnotifies;

    /*
     * If the user supplies a parameter on the command line, use it as the
     * conninfo string; otherwise default to setting dbname=postgres and using
     * environment variables or defaults for all other connection parameters.
     */
    if (argc > 1)
        conninfo = argv[1];
    else
        conninfo = "dbname = postgres";

    /* Make a connection to the database */
    conn = PQconnectdb(conninfo);

    /* Check to see that the backend connection was successfully made */
    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
                PQerrorMessage(conn));
        exit_nicely(conn);
    }

    /*
     * Issue LISTEN command to enable notifications from the rule's NOTIFY.
     */
    res = PQexec(conn, "LISTEN TBL2");
    if (PQresultStatus(res) != PGRES_COMMAND_OK)
```

```
    {
        fprintf(stderr, "LISTEN command failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    /*
     * should PQclear PGresult whenever it is no longer needed to avoid memory
     * leaks
     */
    PQclear(res);

    /* Quit after four notifies are received. */
    nnotifies = 0;
    while (nnotifies < 4)
    {
        /*
         * Sleep until something happens on the connection.  We use select(2)
         * to wait for input, but you could also use poll() or similar
         * facilities.
         */
        int         sock;
        fd_set      input_mask;

        sock = PQsocket(conn);

        if (sock < 0)
            break;              /* shouldn't happen */

        FD_ZERO(&input_mask);
        FD_SET(sock, &input_mask);

        if (select(sock + 1, &input_mask, NULL, NULL, NULL) < 0)
        {
            fprintf(stderr, "select() failed: %s\n", strerror(errno));
            exit_nicely(conn);
        }

        /* Now check for input */
        PQconsumeInput(conn);
        while ((notify = PQnotifies(conn)) != NULL)
        {
            fprintf(stderr,
                    "ASYNC NOTIFY of '%s' received from backend PID %d\n",
                    notify->relname, notify->be_pid);
            PQfreemem(notify);
            nnotifies++;
        }
    }

    fprintf(stderr, "Done.\n");

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}
```

Example 31-3. libpq Example Program 3

```
/*
 * testlibpq3.c
 *      Test out-of-line parameters and binary I/O.
 *
 * Before running this, populate a database with the following commands
 * (provided in src/test/examples/testlibpq3.sql):
 *
 * CREATE TABLE test1 (i int4, t text, b bytea);
 *
 * INSERT INTO test1 values (1, 'joe"s place', '\\000\\001\\002\\003\\004');
 * INSERT INTO test1 values (2, 'ho there', '\\004\\003\\002\\001\\000');
 *
 * The expected output is:
 *
 * tuple 0: got
 *  i = (4 bytes) 1
 *  t = (11 bytes) 'joe's place'
 *  b = (5 bytes) \000\001\002\003\004
 *
 * tuple 0: got
 *  i = (4 bytes) 2
 *  t = (8 bytes) 'ho there'
 *  b = (5 bytes) \004\003\002\001\000
 */

#ifdef WIN32
#include <windows.h>
#endif

#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <string.h>
#include <sys/types.h>
#include "libpq-fe.h"

/* for ntohl/htonl */
#include <netinet/in.h>
#include <arpa/inet.h>


static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

/*
 * This function prints a query result that is a binary-format fetch from
 * a table defined as in the comment above.  We split it out because the
 * main() function uses it twice.
 */
static void
show_binary_results(PGresult *res)
```

```
{
    int         i,
                j;
    int         i_fnum,
                t_fnum,
                b_fnum;

    /* Use PQfnumber to avoid assumptions about field order in result */
    i_fnum = PQfnumber(res, "i");
    t_fnum = PQfnumber(res, "t");
    b_fnum = PQfnumber(res, "b");

    for (i = 0; i < PQntuples(res); i++)
    {
        char       *iptr;
        char       *tptr;
        char       *bptr;
        int         blen;
        int         ival;

        /* Get the field values (we ignore possibility they are null!) */
        iptr = PQgetvalue(res, i, i_fnum);
        tptr = PQgetvalue(res, i, t_fnum);
        bptr = PQgetvalue(res, i, b_fnum);

        /*
         * The binary representation of INT4 is in network byte order, which
         * we'd better coerce to the local byte order.
         */
        ival = ntohl(*((uint32_t *) iptr));

        /*
         * The binary representation of TEXT is, well, text, and since libpq
         * was nice enough to append a zero byte to it, it'll work just fine
         * as a C string.
         *
         * The binary representation of BYTEA is a bunch of bytes, which could
         * include embedded nulls so we have to pay attention to field length.
         */
        blen = PQgetlength(res, i, b_fnum);

        printf("tuple %d: got\n", i);
        printf(" i = (%d bytes) %d\n",
               PQgetlength(res, i, i_fnum), ival);
        printf(" t = (%d bytes) '%s'\n",
               PQgetlength(res, i, t_fnum), tptr);
        printf(" b = (%d bytes) ", blen);
        for (j = 0; j < blen; j++)
            printf("\\%03o", bptr[j]);
        printf("\n\n");
    }
}

int
main(int argc, char **argv)
{
    const char *conninfo;
```

```
PGconn     *conn;
PGresult   *res;
const char *paramValues[1];
int         paramLengths[1];
int         paramFormats[1];
uint32_t    binaryIntVal;

/*
 * If the user supplies a parameter on the command line, use it as the
 * conninfo string; otherwise default to setting dbname=postgres and using
 * environment variables or defaults for all other connection parameters.
 */
if (argc > 1)
    conninfo = argv[1];
else
    conninfo = "dbname = postgres";

/* Make a connection to the database */
conn = PQconnectdb(conninfo);

/* Check to see that the backend connection was successfully made */
if (PQstatus(conn) != CONNECTION_OK)
{
    fprintf(stderr, "Connection to database failed: %s",
            PQerrorMessage(conn));
    exit_nicely(conn);
}

/*
 * The point of this program is to illustrate use of PQexecParams() with
 * out-of-line parameters, as well as binary transmission of data.
 *
 * This first example transmits the parameters as text, but receives the
 * results in binary format.  By using out-of-line parameters we can avoid
 * a lot of tedious mucking about with quoting and escaping, even though
 * the data is text.  Notice how we don't have to do anything special with
 * the quote mark in the parameter value.
 */

/* Here is our out-of-line parameter value */
paramValues[0] = "joe's place";

res = PQexecParams(conn,
                   "SELECT * FROM test1 WHERE t = $1",
                   1,       /* one param */
                   NULL,    /* let the backend deduce param type */
                   paramValues,
                   NULL,    /* don't need param lengths since text */
                   NULL,    /* default to all text params */
                   1);      /* ask for binary results */

if (PQresultStatus(res) != PGRES_TUPLES_OK)
{
    fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
    PQclear(res);
    exit_nicely(conn);
}
```

```
    show_binary_results(res);

    PQclear(res);

    /*
     * In this second example we transmit an integer parameter in binary form,
     * and again retrieve the results in binary form.
     *
     * Although we tell PQexecParams we are letting the backend deduce
     * parameter type, we really force the decision by casting the parameter
     * symbol in the query text.  This is a good safety measure when sending
     * binary parameters.
     */

    /* Convert integer value "2" to network byte order */
    binaryIntVal = htonl((uint32_t) 2);

    /* Set up parameter arrays for PQexecParams */
    paramValues[0] = (char *) &binaryIntVal;
    paramLengths[0] = sizeof(binaryIntVal);
    paramFormats[0] = 1;        /* binary */

    res = PQexecParams(conn,
                       "SELECT * FROM test1 WHERE i = $1::int4",
                       1,       /* one param */
                       NULL,    /* let the backend deduce param type */
                       paramValues,
                       paramLengths,
                       paramFormats,
                       1);      /* ask for binary results */

    if (PQresultStatus(res) != PGRES_TUPLES_OK)
    {
        fprintf(stderr, "SELECT failed: %s", PQerrorMessage(conn));
        PQclear(res);
        exit_nicely(conn);
    }

    show_binary_results(res);

    PQclear(res);

    /* close the connection to the database and cleanup */
    PQfinish(conn);

    return 0;
}
```

Chapter 32. Large Objects

PostgreSQL has a *large object* facility, which provides stream-style access to user data that is stored in a special large-object structure. Streaming access is useful when working with data values that are too large to manipulate conveniently as a whole.

This chapter describes the implementation and the programming and query language interfaces to PostgreSQL large object data. We use the libpq C library for the examples in this chapter, but most programming interfaces native to PostgreSQL support equivalent functionality. Other interfaces might use the large object interface internally to provide generic support for large values. This is not described here.

32.1. Introduction

All large objects are stored in a single system table named `pg_largeobject`. Each large object also has an entry in the system table `pg_largeobject_metadata`. Large objects can be created, modified, and deleted using a read/write API that is similar to standard operations on files.

PostgreSQL also supports a storage system called "TOAST", which automatically stores values larger than a single database page into a secondary storage area per table. This makes the large object facility partially obsolete. One remaining advantage of the large object facility is that it allows values up to 4 TB in size, whereas TOASTed fields can be at most 1 GB. Also, reading and updating portions of a large object can be done efficiently, while most operations on a TOASTed field will read or write the whole value as a unit.

32.2. Implementation Features

The large object implementation breaks large objects up into "chunks" and stores the chunks in rows in the database. A B-tree index guarantees fast searches for the correct chunk number when doing random access reads and writes.

The chunks stored for a large object do not have to be contiguous. For example, if an application opens a new large object, seeks to offset 1000000, and writes a few bytes there, this does not result in allocation of 1000000 bytes worth of storage; only of chunks covering the range of data bytes actually written. A read operation will, however, read out zeroes for any unallocated locations preceding the last existing chunk. This corresponds to the common behavior of "sparsely allocated" files in Unix file systems.

As of PostgreSQL 9.0, large objects have an owner and a set of access permissions, which can be managed using GRANT and REVOKE. `SELECT` privileges are required to read a large object, and `UPDATE` privileges are required to write or truncate it. Only the large object's owner (or a database superuser) can delete, comment on, or change the owner of a large object. To adjust this behavior for compatibility with prior releases, see the lo_compat_privileges run-time parameter.

32.3. Client Interfaces

This section describes the facilities that PostgreSQL's libpq client interface library provides for accessing large objects. The PostgreSQL large object interface is modeled after the Unix file-system interface, with analogues of `open`, `read`, `write`, `lseek`, etc.

All large object manipulation using these functions *must* take place within an SQL transaction block, since large object file descriptors are only valid for the duration of a transaction.

If an error occurs while executing any one of these functions, the function will return an otherwise-impossible value, typically 0 or -1. A message describing the error is stored in the connection object and can be retrieved with `PQerrorMessage`.

Client applications that use these functions should include the header file `libpq/libpq-fs.h` and link with the libpq library.

32.3.1. Creating a Large Object

The function

```
Oid lo_creat(PGconn *conn, int mode);
```

creates a new large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. *`mode`* is unused and ignored as of PostgreSQL 8.1; however, for backward compatibility with earlier releases it is best to set it to `INV_READ`, `INV_WRITE`, or `INV_READ | INV_WRITE`. (These symbolic constants are defined in the header file `libpq/libpq-fs.h`.)

An example:

```
inv_oid = lo_creat(conn, INV_READ|INV_WRITE);
```

The function

```
Oid lo_create(PGconn *conn, Oid lobjId);
```

also creates a new large object. The OID to be assigned can be specified by *`lobjId`*; if so, failure occurs if that OID is already in use for some large object. If *`lobjId`* is `InvalidOid` (zero) then `lo_create` assigns an unused OID (this is the same behavior as `lo_creat`). The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure.

`lo_create` is new as of PostgreSQL 8.1; if this function is run against an older server version, it will fail and return `InvalidOid`.

An example:

```
inv_oid = lo_create(conn, desired_oid);
```

32.3.2. Importing a Large Object

To import an operating system file as a large object, call

```
Oid lo_import(PGconn *conn, const char *filename);
```

`filename` specifies the operating system name of the file to be imported as a large object. The return value is the OID that was assigned to the new large object, or `InvalidOid` (zero) on failure. Note that the file is read by the client interface library, not by the server; so it must exist in the client file system and be readable by the client application.

The function

```
Oid lo_import_with_oid(PGconn *conn, const char *filename, Oid lobjId);
```

also imports a new large object. The OID to be assigned can be specified by *lobjId*; if so, failure occurs if that OID is already in use for some large object. If *lobjId* is InvalidOid (zero) then lo_import_with_oid assigns an unused OID (this is the same behavior as lo_import). The return value is the OID that was assigned to the new large object, or InvalidOid (zero) on failure.

lo_import_with_oid is new as of PostgreSQL 8.4 and uses lo_create internally which is new in 8.1; if this function is run against 8.0 or before, it will fail and return InvalidOid.

32.3.3. Exporting a Large Object

To export a large object into an operating system file, call

```
int lo_export(PGconn *conn, Oid lobjId, const char *filename);
```

The lobjId argument specifies the OID of the large object to export and the filename argument specifies the operating system name of the file. Note that the file is written by the client interface library, not by the server. Returns 1 on success, -1 on failure.

32.3.4. Opening an Existing Large Object

To open an existing large object for reading or writing, call

```
int lo_open(PGconn *conn, Oid lobjId, int mode);
```

The lobjId argument specifies the OID of the large object to open. The mode bits control whether the object is opened for reading (INV_READ), writing (INV_WRITE), or both. (These symbolic constants are defined in the header file libpq/libpq-fs.h.) lo_open returns a (non-negative) large object descriptor for later use in lo_read, lo_write, lo_lseek, lo_lseek64, lo_tell, lo_tell64, lo_truncate, lo_truncate64, and lo_close. The descriptor is only valid for the duration of the current transaction. On failure, -1 is returned.

The server currently does not distinguish between modes INV_WRITE and INV_READ | INV_WRITE: you are allowed to read from the descriptor in either case. However there is a significant difference between these modes and INV_READ alone: with INV_READ you cannot write on the descriptor, and the data read from it will reflect the contents of the large object at the time of the transaction snapshot that was active when lo_open was executed, regardless of later writes by this or other transactions. Reading from a descriptor opened with INV_WRITE returns data that reflects all writes of other committed transactions as well as writes of the current transaction. This is similar to the behavior of REPEATABLE READ versus READ COMMITTED transaction modes for ordinary SQL SELECT commands.

An example:

```
inv_fd = lo_open(conn, inv_oid, INV_READ|INV_WRITE);
```

32.3.5. Writing Data to a Large Object

The function

```
int lo_write(PGconn *conn, int fd, const char *buf, size_t len);
```

writes `len` bytes from `buf` (which must be of size `len`) to large object descriptor `fd`. The `fd` argument must have been returned by a previous `lo_open`. The number of bytes actually written is returned (in the current implementation, this will always equal `len` unless there is an error). In the event of an error, the return value is -1.

Although the `len` parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

32.3.6. Reading Data from a Large Object

The function

```
int lo_read(PGconn *conn, int fd, char *buf, size_t len);
```

reads up to `len` bytes from large object descriptor `fd` into `buf` (which must be of size `len`). The `fd` argument must have been returned by a previous `lo_open`. The number of bytes actually read is returned; this will be less than `len` if the end of the large object is reached first. In the event of an error, the return value is -1.

Although the `len` parameter is declared as `size_t`, this function will reject length values larger than `INT_MAX`. In practice, it's best to transfer data in chunks of at most a few megabytes anyway.

32.3.7. Seeking in a Large Object

To change the current read or write location associated with a large object descriptor, call

```
int lo_lseek(PGconn *conn, int fd, int offset, int whence);
```

This function moves the current location pointer for the large object descriptor identified by `fd` to the new location specified by `offset`. The valid values for `whence` are `SEEK_SET` (seek from object start), `SEEK_CUR` (seek from current position), and `SEEK_END` (seek from object end). The return value is the new location pointer, or -1 on error.

When dealing with large objects that might exceed 2GB in size, instead use

```
pg_int64 lo_lseek64(PGconn *conn, int fd, pg_int64 offset, int whence);
```

This function has the same behavior as `lo_lseek`, but it can accept an `offset` larger than 2GB and/or deliver a result larger than 2GB. Note that `lo_lseek` will fail if the new location pointer would be greater than 2GB.

`lo_lseek64` is new as of PostgreSQL 9.3. If this function is run against an older server version, it will fail and return -1.

32.3.8. Obtaining the Seek Position of a Large Object

To obtain the current read or write location of a large object descriptor, call

```
int lo_tell(PGconn *conn, int fd);
```

If there is an error, the return value is -1.

When dealing with large objects that might exceed 2GB in size, instead use

```
pg_int64 lo_tell64(PGconn *conn, int fd);
```

This function has the same behavior as `lo_tell`, but it can deliver a result larger than 2GB. Note that `lo_tell` will fail if the current read/write location is greater than 2GB.

`lo_tell64` is new as of PostgreSQL 9.3. If this function is run against an older server version, it will fail and return -1.

32.3.9. Truncating a Large Object

To truncate a large object to a given length, call

```
int lo_truncate(PGcon *conn, int fd, size_t len);
```

This function truncates the large object descriptor `fd` to length `len`. The `fd` argument must have been returned by a previous `lo_open`. If `len` is greater than the large object's current length, the large object is extended to the specified length with null bytes ('\0'). On success, `lo_truncate` returns zero. On error, the return value is -1.

The read/write location associated with the descriptor `fd` is not changed.

Although the `len` parameter is declared as `size_t`, `lo_truncate` will reject length values larger than `INT_MAX`.

When dealing with large objects that might exceed 2GB in size, instead use

```
int lo_truncate64(PGcon *conn, int fd, pg_int64 len);
```

This function has the same behavior as `lo_truncate`, but it can accept a `len` value exceeding 2GB.

`lo_truncate` is new as of PostgreSQL 8.3; if this function is run against an older server version, it will fail and return -1.

`lo_truncate64` is new as of PostgreSQL 9.3; if this function is run against an older server version, it will fail and return -1.

32.3.10. Closing a Large Object Descriptor

A large object descriptor can be closed by calling

```
int lo_close(PGconn *conn, int fd);
```

where `fd` is a large object descriptor returned by `lo_open`. On success, `lo_close` returns zero. On error, the return value is -1.

Any large object descriptors that remain open at the end of a transaction will be closed automatically.

32.3.11. Removing a Large Object

To remove a large object from the database, call

```
int lo_unlink(PGconn *conn, Oid lobjId);
```

The `lobjId` argument specifies the OID of the large object to remove. Returns 1 if successful, -1 on failure.

32.4. Server-side Functions

Server-side functions tailored for manipulating large objects from SQL are listed in Table 32-1.

Table 32-1. SQL-oriented Large Object Functions

Function	Return Type	Description	Example	Result
lo_from_bytea(loid oid, string bytea)	oid	Create a large object and store data there, returning its OID. Pass 0 to have the system choose an OID.	lo_from_bytea(0, E'\\xffffff00')	24528
lo_put(loid oid, offset bigint, str bytea)	void	Write data at the given offset.	lo_put(24528, 1, E'\\xaa')	
lo_get(loid oid [, from bigint, for int])	bytea	Extract contents or a substring thereof.	lo_get(24528, 0, 3)	\xffaaff

There are additional server-side functions corresponding to each of the client-side functions described earlier; indeed, for the most part the client-side functions are simply interfaces to the equivalent server-side functions. The ones just as convenient to call via SQL commands are lo_creat, lo_create, lo_unlink, lo_import, and lo_export. Here are examples of their use:

```
CREATE TABLE image (
    name            text,
    raster          oid
);

SELECT lo_creat(-1);       -- returns OID of new, empty large object

SELECT lo_create(43213);   -- attempts to create large object with OID 43213

SELECT lo_unlink(173454);  -- deletes large object with OID 173454

INSERT INTO image (name, raster)
    VALUES ('beautiful image', lo_import('/etc/motd'));

INSERT INTO image (name, raster)  -- same as above, but specify OID to use
    VALUES ('beautiful image', lo_import('/etc/motd', 68583));

SELECT lo_export(image.raster, '/tmp/motd') FROM image
    WHERE name = 'beautiful image';
```

The server-side lo_import and lo_export functions behave considerably differently from their client-side analogs. These two functions read and write files in the server's file system, using the permissions of the database's owning user. Therefore, their use is restricted to superusers. In contrast, the client-side import and export functions read and write files in the client's file system, using the permissions of the client program. The client-side functions do not require superuser privilege.

The functionality of `lo_read` and `lo_write` is also available via server-side calls, but the names of the server-side functions differ from the client side interfaces in that they do not contain underscores. You must call these functions as `loread` and `lowrite`.

32.5. Example Program

Example 32-1 is a sample program which shows how the large object interface in libpq can be used. Parts of the program are commented out but are left in the source for the reader's benefit. This program can also be found in `src/test/examples/testlo.c` in the source distribution.

Example 32-1. Large Objects with libpq Example Program

```
/*--------------------------------------------------------------------------
 *
 * testlo.c
 *    test using large objects with libpq
 *
 * Portions Copyright (c) 1996-2014, PostgreSQL Global Development Group
 * Portions Copyright (c) 1994, Regents of the University of California
 *
 *
 * IDENTIFICATION
 *    src/test/examples/testlo.c
 *
 *--------------------------------------------------------------------------
 */
#include <stdio.h>
#include <stdlib.h>

#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <unistd.h>

#include "libpq-fe.h"
#include "libpq/libpq-fs.h"

#define BUFSIZE         1024

/*
 * importFile -
 *    import file "in_filename" into database as large object "lobjOid"
 *
 */
static Oid
importFile(PGconn *conn, char *filename)
{
    Oid         lobjId;
    int         lobj_fd;
    char        buf[BUFSIZE];
    int         nbytes,
                tmp;
    int         fd;
```

```
    /*
     * open the file to be read in
     */
    fd = open(filename, O_RDONLY, 0666);
    if (fd < 0)
    {                           /* error */
        fprintf(stderr, "cannot open unix file\"%s\"\n", filename);
    }

    /*
     * create the large object
     */
    lobjId = lo_creat(conn, INV_READ | INV_WRITE);
    if (lobjId == 0)
        fprintf(stderr, "cannot create large object");

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);

    /*
     * read in from the Unix file and write to the inversion file
     */
    while ((nbytes = read(fd, buf, BUFSIZE)) > 0)
    {
        tmp = lo_write(conn, lobj_fd, buf, nbytes);
        if (tmp < nbytes)
            fprintf(stderr, "error while reading \"%s\"", filename);
    }

    close(fd);
    lo_close(conn, lobj_fd);

    return lobjId;
}

static void
pickout(PGconn *conn, Oid lobjId, int start, int len)
{
    int         lobj_fd;
    char       *buf;
    int         nbytes;
    int         nread;

    lobj_fd = lo_open(conn, lobjId, INV_READ);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    lo_lseek(conn, lobj_fd, start, SEEK_SET);
    buf = malloc(len + 1);

    nread = 0;
    while (len - nread > 0)
    {
        nbytes = lo_read(conn, lobj_fd, buf, len - nread);
        buf[nbytes] = '\0';
        fprintf(stderr, ">>> %s", buf);
        nread += nbytes;
        if (nbytes <= 0)
```

```
            break;              /* no more data? */
    }
    free(buf);
    fprintf(stderr, "\n");
    lo_close(conn, lobj_fd);
}

static void
overwrite(PGconn *conn, Oid lobjId, int start, int len)
{
    int         lobj_fd;
    char       *buf;
    int         nbytes;
    int         nwritten;
    int         i;

    lobj_fd = lo_open(conn, lobjId, INV_WRITE);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    lo_lseek(conn, lobj_fd, start, SEEK_SET);
    buf = malloc(len + 1);

    for (i = 0; i < len; i++)
        buf[i] = 'X';
    buf[i] = '\0';

    nwritten = 0;
    while (len - nwritten > 0)
    {
        nbytes = lo_write(conn, lobj_fd, buf + nwritten, len - nwritten);
        nwritten += nbytes;
        if (nbytes <= 0)
        {
            fprintf(stderr, "\nWRITE FAILED!\n");
            break;
        }
    }
    free(buf);
    fprintf(stderr, "\n");
    lo_close(conn, lobj_fd);
}


/*
 * exportFile -
 *    export large object "lobjOid" to file "out_filename"
 *
 */
static void
exportFile(PGconn *conn, Oid lobjId, char *filename)
{
    int         lobj_fd;
    char        buf[BUFSIZE];
    int         nbytes,
                tmp;
    int         fd;
```

```
    /*
     * open the large object
     */
    lobj_fd = lo_open(conn, lobjId, INV_READ);
    if (lobj_fd < 0)
        fprintf(stderr, "cannot open large object %u", lobjId);

    /*
     * open the file to be written to
     */
    fd = open(filename, O_CREAT | O_WRONLY | O_TRUNC, 0666);
    if (fd < 0)
    {                           /* error */
        fprintf(stderr, "cannot open unix file\"%s\"",
                filename);
    }

    /*
     * read in from the inversion file and write to the Unix file
     */
    while ((nbytes = lo_read(conn, lobj_fd, buf, BUFSIZE)) > 0)
    {
        tmp = write(fd, buf, nbytes);
        if (tmp < nbytes)
        {
            fprintf(stderr, "error while writing \"%s\"",
                    filename);
        }
    }

    lo_close(conn, lobj_fd);
    close(fd);

    return;
}

static void
exit_nicely(PGconn *conn)
{
    PQfinish(conn);
    exit(1);
}

int
main(int argc, char **argv)
{
    char       *in_filename,
               *out_filename;
    char       *database;
    Oid         lobjOid;
    PGconn     *conn;
    PGresult   *res;

    if (argc != 4)
    {
        fprintf(stderr, "Usage: %s database_name in_filename out_filename\n",
```

```
                argv[0]);
        exit(1);
    }

    database = argv[1];
    in_filename = argv[2];
    out_filename = argv[3];

    /*
     * set up the connection
     */
    conn = PQsetdb(NULL, NULL, NULL, NULL, database);

    /* check to see that the backend connection was successfully made */
    if (PQstatus(conn) != CONNECTION_OK)
    {
        fprintf(stderr, "Connection to database failed: %s",
                PQerrorMessage(conn));
        exit_nicely(conn);
    }

    res = PQexec(conn, "begin");
    PQclear(res);
    printf("importing file \"%s\" ...\n", in_filename);
/*  lobjOid = importFile(conn, in_filename); */
    lobjOid = lo_import(conn, in_filename);
    if (lobjOid == 0)
        fprintf(stderr, "%s\n", PQerrorMessage(conn));
    else
    {
        printf("\tas large object %u.\n", lobjOid);

        printf("picking out bytes 1000-2000 of the large object\n");
        pickout(conn, lobjOid, 1000, 1000);

        printf("overwriting bytes 1000-2000 of the large object with X's\n");
        overwrite(conn, lobjOid, 1000, 1000);

        printf("exporting large object to file \"%s\" ...\n", out_filename);
/*      exportFile(conn, lobjOid, out_filename); */
        if (lo_export(conn, lobjOid, out_filename) < 0)
            fprintf(stderr, "%s\n", PQerrorMessage(conn));
    }

    res = PQexec(conn, "end");
    PQclear(res);
    PQfinish(conn);
    return 0;
}
```

Chapter 33. ECPG - Embedded SQL in C

This chapter describes the embedded SQL package for PostgreSQL. It was written by Linus Tolke (<linus@epact.se>) and Michael Meskes (<meskes@postgresql.org>). Originally it was written to work with C. It also works with C++, but it does not recognize all C++ constructs yet.

This documentation is quite incomplete. But since this interface is standardized, additional information can be found in many resources about SQL.

33.1. The Concept

An embedded SQL program consists of code written in an ordinary programming language, in this case C, mixed with SQL commands in specially marked sections. To build the program, the source code (*.pgc) is first passed through the embedded SQL preprocessor, which converts it to an ordinary C program (*.c), and afterwards it can be processed by a C compiler. (For details about the compiling and linking see Section 33.10). Converted ECPG applications call functions in the libpq library through the embedded SQL library (ecpglib), and communicate with the PostgreSQL server using the normal frontend-backend protocol.

Embedded SQL has advantages over other methods for handling SQL commands from C code. First, it takes care of the tedious passing of information to and from variables in your C program. Second, the SQL code in the program is checked at build time for syntactical correctness. Third, embedded SQL in C is specified in the SQL standard and supported by many other SQL database systems. The PostgreSQL implementation is designed to match this standard as much as possible, and it is usually possible to port embedded SQL programs written for other SQL databases to PostgreSQL with relative ease.

As already stated, programs written for the embedded SQL interface are normal C programs with special code inserted to perform database-related actions. This special code always has the form:

```
EXEC SQL ...;
```

These statements syntactically take the place of a C statement. Depending on the particular statement, they can appear at the global level or within a function. Embedded SQL statements follow the case-sensitivity rules of normal SQL code, and not those of C. Also they allow nested C-style comments that are part of the SQL standard. The C part of the program, however, follows the C standard of not accepting nested comments.

The following sections explain all the embedded SQL statements.

33.2. Managing Database Connections

This section describes how to open, close, and switch database connections.

33.2.1. Connecting to the Database Server

One connects to a database using the following statement:

```
EXEC SQL CONNECT TO target [AS connection-name] [USER user-name];
```

The *target* can be specified in the following ways:

- *dbname*[@*hostname*][:*port*]
- tcp:postgresql://*hostname*[:*port*][/*dbname*][?*options*]
- unix:postgresql://*hostname*[:*port*][/*dbname*][?*options*]
- an SQL string literal containing one of the above forms
- a reference to a character variable containing one of the above forms (see examples)
- DEFAULT

If you specify the connection target literally (that is, not through a variable reference) and you don't quote the value, then the case-insensitivity rules of normal SQL are applied. In that case you can also double-quote the individual parameters separately as needed. In practice, it is probably less error-prone to use a (single-quoted) string literal or a variable reference. The connection target DEFAULT initiates a connection to the default database under the default user name. No separate user name or connection name can be specified in that case.

There are also different ways to specify the user name:

- *username*
- *username*/*password*
- *username* IDENTIFIED BY *password*
- *username* USING *password*

As above, the parameters *username* and *password* can be an SQL identifier, an SQL string literal, or a reference to a character variable.

The *connection-name* is used to handle multiple connections in one program. It can be omitted if a program uses only one connection. The most recently opened connection becomes the current connection, which is used by default when an SQL statement is to be executed (see later in this chapter).

Here are some examples of CONNECT statements:

```
EXEC SQL CONNECT TO mydb@sql.mydomain.com;

EXEC SQL CONNECT TO unix:postgresql://sql.mydomain.com/mydb AS myconnection USER john;

EXEC SQL BEGIN DECLARE SECTION;
const char *target = "mydb@sql.mydomain.com";
const char *user = "john";
const char *passwd = "secret";
EXEC SQL END DECLARE SECTION;
 ...
EXEC SQL CONNECT TO :target USER :user USING :passwd;
/* or EXEC SQL CONNECT TO :target USER :user/:passwd; */
```

The last form makes use of the variant referred to above as character variable reference. You will see in later sections how C variables can be used in SQL statements when you prefix them with a colon.

Be advised that the format of the connection target is not specified in the SQL standard. So if you want to develop portable applications, you might want to use something based on the last example above to encapsulate the connection target string somewhere.

33.2.2. Choosing a Connection

SQL statements in embedded SQL programs are by default executed on the current connection, that is, the most recently opened one. If an application needs to manage multiple connections, then there are two ways to handle this.

The first option is to explicitly choose a connection for each SQL statement, for example:

```
EXEC SQL AT connection-name SELECT ...;
```

This option is particularly suitable if the application needs to use several connections in mixed order.

If your application uses multiple threads of execution, they cannot share a connection concurrently. You must either explicitly control access to the connection (using mutexes) or use a connection for each thread. If each thread uses its own connection, you will need to use the AT clause to specify which connection the thread will use.

The second option is to execute a statement to switch the current connection. That statement is:

```
EXEC SQL SET CONNECTION connection-name;
```

This option is particularly convenient if many statements are to be executed on the same connection. It is not thread-aware.

Here is an example program managing multiple database connections:

```
#include <stdio.h>

EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
EXEC SQL END DECLARE SECTION;

int
main()
{
    EXEC SQL CONNECT TO testdb1 AS con1 USER testuser;
    EXEC SQL CONNECT TO testdb2 AS con2 USER testuser;
    EXEC SQL CONNECT TO testdb3 AS con3 USER testuser;

    /* This query would be executed in the last opened database "testdb3". */
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb3)\n", dbname);

    /* Using "AT" to run a query in "testdb2" */
    EXEC SQL AT con2 SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb2)\n", dbname);

    /* Switch the current connection to "testdb1". */
    EXEC SQL SET CONNECTION con1;

    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current=%s (should be testdb1)\n", dbname);

    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

This example would produce this output:

```
current=testdb3 (should be testdb3)
current=testdb2 (should be testdb2)
current=testdb1 (should be testdb1)
```

33.2.3. Closing a Connection

To close a connection, use the following statement:

```
EXEC SQL DISCONNECT [connection];
```

The *connection* can be specified in the following ways:

- *connection-name*
- DEFAULT
- CURRENT
- ALL

If no connection name is specified, the current connection is closed.

It is good style that an application always explicitly disconnect from every connection it opened.

33.3. Running SQL Commands

Any SQL command can be run from within an embedded SQL application. Below are some examples of how to do that.

33.3.1. Executing SQL Statements

Creating a table:

```
EXEC SQL CREATE TABLE foo (number integer, ascii char(16));
EXEC SQL CREATE UNIQUE INDEX num1 ON foo(number);
EXEC SQL COMMIT;
```

Inserting rows:

```
EXEC SQL INSERT INTO foo (number, ascii) VALUES (9999, 'doodad');
EXEC SQL COMMIT;
```

Deleting rows:

```
EXEC SQL DELETE FROM foo WHERE number = 9999;
EXEC SQL COMMIT;
```

Updates:

```
EXEC SQL UPDATE foo
    SET ascii = 'foobar'
    WHERE number = 9999;
EXEC SQL COMMIT;
```

SELECT statements that return a single result row can also be executed using EXEC SQL directly. To handle result sets with multiple rows, an application has to use a cursor; see Section 33.3.2 below. (As a special case, an application can fetch multiple rows at once into an array host variable; see Section 33.4.4.3.1.)

Single-row select:

```
EXEC SQL SELECT foo INTO :FooBar FROM table1 WHERE ascii = 'doodad';
```

Also, a configuration parameter can be retrieved with the SHOW command:

```
EXEC SQL SHOW search_path INTO :var;
```

The tokens of the form :*something* are *host variables*, that is, they refer to variables in the C program. They are explained in Section 33.4.

33.3.2. Using Cursors

To retrieve a result set holding multiple rows, an application has to declare a cursor and fetch each row from the cursor. The steps to use a cursor are the following: declare a cursor, open it, fetch a row from the cursor, repeat, and finally close it.

Select using cursors:

```
EXEC SQL DECLARE foo_bar CURSOR FOR
    SELECT number, ascii FROM foo
    ORDER BY ascii;
EXEC SQL OPEN foo_bar;
EXEC SQL FETCH foo_bar INTO :FooBar, DooDad;
...
EXEC SQL CLOSE foo_bar;
EXEC SQL COMMIT;
```

For more details about declaration of the cursor, see DECLARE, and see FETCH for FETCH command details.

> **Note:** The ECPG DECLARE command does not actually cause a statement to be sent to the PostgreSQL backend. The cursor is opened in the backend (using the backend's DECLARE command) at the point when the OPEN command is executed.

33.3.3. Managing Transactions

In the default mode, statements are committed only when `EXEC SQL COMMIT` is issued. The embedded SQL interface also supports autocommit of transactions (similar to libpq behavior) via the `-t` command-line option to `ecpg` (see ecpg) or via the `EXEC SQL SET AUTOCOMMIT TO ON` statement. In autocommit mode, each command is automatically committed unless it is inside an explicit transaction block. This mode can be explicitly turned off using `EXEC SQL SET AUTOCOMMIT TO OFF`.

The following transaction management commands are available:

`EXEC SQL COMMIT`

Commit an in-progress transaction.

`EXEC SQL ROLLBACK`

Roll back an in-progress transaction.

`EXEC SQL SET AUTOCOMMIT TO ON`

Enable autocommit mode.

`SET AUTOCOMMIT TO OFF`

Disable autocommit mode. This is the default.

33.3.4. Prepared Statements

When the values to be passed to an SQL statement are not known at compile time, or the same statement is going to be used many times, then prepared statements can be useful.

The statement is prepared using the command `PREPARE`. For the values that are not known yet, use the placeholder "`?`":

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid, datname FROM pg_database WHERE oid = ?";
```

If a statement returns a single row, the application can call `EXECUTE` after `PREPARE` to execute the statement, supplying the actual values for the placeholders with a `USING` clause:

```
EXEC SQL EXECUTE stmt1 INTO :dboid, :dbname USING 1;
```

If a statement returns multiple rows, the application can use a cursor declared based on the prepared statement. To bind input parameters, the cursor must be opened with a `USING` clause:

```
EXEC SQL PREPARE stmt1 FROM "SELECT oid,datname FROM pg_database WHERE oid > ?";
EXEC SQL DECLARE foo_bar CURSOR FOR stmt1;

/* when end of result set reached, break out of while loop */
EXEC SQL WHENEVER NOT FOUND DO BREAK;

EXEC SQL OPEN foo_bar USING 100;
...
while (1)
{
```

```
    EXEC SQL FETCH NEXT FROM foo_bar INTO :dboid, :dbname;
    ...
}
EXEC SQL CLOSE foo_bar;
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

For more details about `PREPARE`, see PREPARE. Also see Section 33.5 for more details about using placeholders and input parameters.

33.4. Using Host Variables

In Section 33.3 you saw how you can execute SQL statements from an embedded SQL program. Some of those statements only used fixed values and did not provide a way to insert user-supplied values into statements or have the program process the values returned by the query. Those kinds of statements are not really useful in real applications. This section explains in detail how you can pass data between your C program and the embedded SQL statements using a simple mechanism called *host variables*. In an embedded SQL program we consider the SQL statements to be *guests* in the C program code which is the *host language*. Therefore the variables of the C program are called *host variables*.

Another way to exchange values between PostgreSQL backends and ECPG applications is the use of SQL descriptors, described in Section 33.7.

33.4.1. Overview

Passing data between the C program and the SQL statements is particularly simple in embedded SQL. Instead of having the program paste the data into the statement, which entails various complications, such as properly quoting the value, you can simply write the name of a C variable into the SQL statement, prefixed by a colon. For example:

```
EXEC SQL INSERT INTO sometable VALUES (:v1, 'foo', :v2);
```

This statements refers to two C variables named `v1` and `v2` and also uses a regular SQL string literal, to illustrate that you are not restricted to use one kind of data or the other.

This style of inserting C variables in SQL statements works anywhere a value expression is expected in an SQL statement.

33.4.2. Declare Sections

To pass data from the program to the database, for example as parameters in a query, or to pass data from the database back to the program, the C variables that are intended to contain this data need to be declared in specially marked sections, so the embedded SQL preprocessor is made aware of them.

This section starts with:

```
EXEC SQL BEGIN DECLARE SECTION;
```

and ends with:

```
EXEC SQL END DECLARE SECTION;
```

Between those lines, there must be normal C variable declarations, such as:

```
int   x = 4;
char  foo[16], bar[16];
```

As you can see, you can optionally assign an initial value to the variable. The variable's scope is determined by the location of its declaring section within the program. You can also declare variables with the following syntax which implicitly creates a declare section:

```
EXEC SQL int i = 4;
```

You can have as many declare sections in a program as you like.

The declarations are also echoed to the output file as normal C variables, so there's no need to declare them again. Variables that are not intended to be used in SQL commands can be declared normally outside these special sections.

The definition of a structure or union also must be listed inside a `DECLARE` section. Otherwise the preprocessor cannot handle these types since it does not know the definition.

33.4.3. Retrieving Query Results

Now you should be able to pass data generated by your program into an SQL command. But how do you retrieve the results of a query? For that purpose, embedded SQL provides special variants of the usual commands `SELECT` and `FETCH`. These commands have a special `INTO` clause that specifies which host variables the retrieved values are to be stored in. `SELECT` is used for a query that returns only single row, and `FETCH` is used for a query that returns multiple rows, using a cursor.

Here is an example:

```
/*
 * assume this table:
 * CREATE TABLE test1 (a int, b varchar(50));
 */

EXEC SQL BEGIN DECLARE SECTION;
int v1;
VARCHAR v2;
EXEC SQL END DECLARE SECTION;

 ...

EXEC SQL SELECT a, b INTO :v1, :v2 FROM test;
```

So the `INTO` clause appears between the select list and the `FROM` clause. The number of elements in the select list and the list after `INTO` (also called the target list) must be equal.

Here is an example using the command `FETCH`:

```
EXEC SQL BEGIN DECLARE SECTION;
int v1;
```

```
VARCHAR v2;
EXEC SQL END DECLARE SECTION;

 ...

EXEC SQL DECLARE foo CURSOR FOR SELECT a, b FROM test;

 ...

do
{
    ...
    EXEC SQL FETCH NEXT FROM foo INTO :v1, :v2;
    ...
} while (...);
```

Here the `INTO` clause appears after all the normal clauses.

33.4.4. Type Mapping

When ECPG applications exchange values between the PostgreSQL server and the C application, such as when retrieving query results from the server or executing SQL statements with input parameters, the values need to be converted between PostgreSQL data types and host language variable types (C language data types, concretely). One of the main points of ECPG is that it takes care of this automatically in most cases.

In this respect, there are two kinds of data types: Some simple PostgreSQL data types, such as `integer` and `text`, can be read and written by the application directly. Other PostgreSQL data types, such as `timestamp` and `numeric` can only be accessed through special library functions; see Section 33.4.4.2.

Table 33-1 shows which PostgreSQL data types correspond to which C data types. When you wish to send or receive a value of a given PostgreSQL data type, you should declare a C variable of the corresponding C data type in the declare section.

Table 33-1. Mapping Between PostgreSQL Data Types and C Variable Types

PostgreSQL data type	Host variable type
`smallint`	`short`
`integer`	`int`
`bigint`	`long long int`
`decimal`	`decimal`[a]
`numeric`	`numeric`[a]
`real`	`float`
`double precision`	`double`
`smallserial`	`short`
`serial`	`int`
`bigserial`	`long long int`
`oid`	`unsigned int`
`character(`*n*`)`, `varchar(`*n*`)`, `text`	`char[`*n*`+1]`, `VARCHAR[`*n*`+1]`[b]
`name`	`char[NAMEDATALEN]`

PostgreSQL data type	Host variable type
timestamp	timestamp[a]
interval	interval[a]
date	date[a]
boolean	bool[c]

Notes:
a. This type can only be accessed through special library functions; see Section 33.4.4.2.
b. declared in ecpglib.h
c. declared in ecpglib.h if not native

33.4.4.1. Handling Character Strings

To handle SQL character string data types, such as varchar and text, there are two possible ways to declare the host variables.

One way is using char[], an array of char, which is the most common way to handle character data in C.

```
EXEC SQL BEGIN DECLARE SECTION;
    char str[50];
EXEC SQL END DECLARE SECTION;
```

Note that you have to take care of the length yourself. If you use this host variable as the target variable of a query which returns a string with more than 49 characters, a buffer overflow occurs.

The other way is using the VARCHAR type, which is a special type provided by ECPG. The definition on an array of type VARCHAR is converted into a named struct for every variable. A declaration like:

```
VARCHAR var[180];
```

is converted into:

```
struct varchar_var { int len; char arr[180]; } var;
```

The member arr hosts the string including a terminating zero byte. Thus, to store a string in a VARCHAR host variable, the host variable has to be declared with the length including the zero byte terminator. The member len holds the length of the string stored in the arr without the terminating zero byte. When a host variable is used as input for a query, if strlen(arr) and len are different, the shorter one is used.

VARCHAR can be written in upper or lower case, but not in mixed case.

char and VARCHAR host variables can also hold values of other SQL types, which will be stored in their string forms.

33.4.4.2. Accessing Special Data Types

ECPG contains some special types that help you to interact easily with some special data types from the PostgreSQL server. In particular, it has implemented support for the numeric, decimal, date, timestamp, and interval types. These data types cannot usefully be mapped to primitive host variable types (such as int, long long int, or char[]), because they have a complex internal structure. Applications deal with these types by declaring host variables in special types and accessing them using functions in the pgtypes library. The pgtypes library, described in detail in Section 33.6

contains basic functions to deal with those types, such that you do not need to send a query to the SQL server just for adding an interval to a time stamp for example.

The follow subsections describe these special data types. For more details about pgtypes library functions, see Section 33.6.

33.4.4.2.1. timestamp, date

Here is a pattern for handling `timestamp` variables in the ECPG host application.

First, the program has to include the header file for the `timestamp` type:

```
#include <pgtypes_timestamp.h>
```

Next, declare a host variable as type `timestamp` in the declare section:

```
EXEC SQL BEGIN DECLARE SECTION;
timestamp ts;
EXEC SQL END DECLARE SECTION;
```

And after reading a value into the host variable, process it using pgtypes library functions. In following example, the `timestamp` value is converted into text (ASCII) form with the `PGTYPEStimestamp_to_asc()` function:

```
EXEC SQL SELECT now()::timestamp INTO :ts;

printf("ts = %s\n", PGTYPEStimestamp_to_asc(ts));
```

This example will show some result like following:

```
ts = 2010-06-27 18:03:56.949343
```

In addition, the DATE type can be handled in the same way. The program has to include `pgtypes_date.h`, declare a host variable as the date type and convert a DATE value into a text form using `PGTYPESdate_to_asc()` function. For more details about the pgtypes library functions, see Section 33.6.

33.4.4.2.2. interval

The handling of the `interval` type is also similar to the `timestamp` and `date` types. It is required, however, to allocate memory for an `interval` type value explicitly. In other words, the memory space for the variable has to be allocated in the heap memory, not in the stack memory.

Here is an example program:

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_interval.h>

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
```

```
    interval *in;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb;

    in = PGTYPESinterval_new();
    EXEC SQL SELECT '1 min'::interval INTO :in;
    printf("interval = %s\n", PGTYPESinterval_to_asc(in));
    PGTYPESinterval_free(in);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

33.4.4.2.3. numeric, decimal

The handling of the `numeric` and `decimal` types is similar to the `interval` type: It requires defining a pointer, allocating some memory space on the heap, and accessing the variable using the pgtypes library functions. For more details about the pgtypes library functions, see Section 33.6.

No functions are provided specifically for the `decimal` type. An application has to convert it to a `numeric` variable using a pgtypes library function to do further processing.

Here is an example program handling `numeric` and `decimal` type variables.

```
#include <stdio.h>
#include <stdlib.h>
#include <pgtypes_numeric.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    numeric *num;
    numeric *num2;
    decimal *dec;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb;

    num = PGTYPESnumeric_new();
    dec = PGTYPESdecimal_new();

    EXEC SQL SELECT 12.345::numeric(4,2), 23.456::decimal(4,2) INTO :num, :dec;

    printf("numeric = %s\n", PGTYPESnumeric_to_asc(num, 0));
    printf("numeric = %s\n", PGTYPESnumeric_to_asc(num, 1));
    printf("numeric = %s\n", PGTYPESnumeric_to_asc(num, 2));

    /* Convert decimal to numeric to show a decimal value. */
    num2 = PGTYPESnumeric_new();
    PGTYPESnumeric_from_decimal(dec, num2);
```

```
    printf("decimal = %s\n", PGTYPESnumeric_to_asc(num2, 0));
    printf("decimal = %s\n", PGTYPESnumeric_to_asc(num2, 1));
    printf("decimal = %s\n", PGTYPESnumeric_to_asc(num2, 2));

    PGTYPESnumeric_free(num2);
    PGTYPESdecimal_free(dec);
    PGTYPESnumeric_free(num);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

33.4.4.3. Host Variables with Nonprimitive Types

As a host variable you can also use arrays, typedefs, structs, and pointers.

33.4.4.3.1. Arrays

There are two use cases for arrays as host variables. The first is a way to store some text string in `char[]` or `VARCHAR[]`, as explained Section 33.4.4.1. The second use case is to retrieve multiple rows from a query result without using a cursor. Without an array, to process a query result consisting of multiple rows, it is required to use a cursor and the `FETCH` command. But with array host variables, multiple rows can be received at once. The length of the array has to be defined to be able to accommodate all rows, otherwise a buffer overflow will likely occur.

Following example scans the `pg_database` system table and shows all OIDs and names of the available databases:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int dbid[8];
    char dbname[8][16];
    int i;
EXEC SQL END DECLARE SECTION;

    memset(dbname, 0, sizeof(char)* 16 * 8);
    memset(dbid, 0, sizeof(int) * 8);

    EXEC SQL CONNECT TO testdb;

    /* Retrieve multiple rows into arrays at once. */
    EXEC SQL SELECT oid,datname INTO :dbid, :dbname FROM pg_database;

    for (i = 0; i < 8; i++)
        printf("oid=%d, dbname=%s\n", dbid[i], dbname[i]);

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
```

```
}
```

This example shows following result. (The exact values depend on local circumstances.)

```
oid=1, dbname=template1
oid=11510, dbname=template0
oid=11511, dbname=postgres
oid=313780, dbname=testdb
oid=0, dbname=
oid=0, dbname=
oid=0, dbname=
```

33.4.4.3.2. Structures

A structure whose member names match the column names of a query result, can be used to retrieve multiple columns at once. The structure enables handling multiple column values in a single host variable.

The following example retrieves OIDs, names, and sizes of the available databases from the `pg_database` system table and using the `pg_database_size()` function. In this example, a structure variable `dbinfo_t` with members whose names match each column in the `SELECT` result is used to retrieve one result row without putting multiple host variables in the `FETCH` statement.

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef struct
    {
       int oid;
       char datname[65];
       long long int size;
    } dbinfo_t;

    dbinfo_t dbval;
EXEC SQL END DECLARE SECTION;

    memset(&dbval, 0, sizeof(dbinfo_t));

    EXEC SQL DECLARE cur1 CURSOR FOR SELECT oid, datname, pg_database_size(oid) AS size
    EXEC SQL OPEN cur1;

    /* when end of result set reached, break out of while loop */
    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
        /* Fetch multiple columns into one structure. */
        EXEC SQL FETCH FROM cur1 INTO :dbval;

        /* Print members of the structure. */
        printf("oid=%d, datname=%s, size=%lld\n", dbval.oid, dbval.datname, dbval.size);
    }

    EXEC SQL CLOSE cur1;
```

This example shows following result. (The exact values depend on local circumstances.)

```
oid=1, datname=template1, size=4324580
oid=11510, datname=template0, size=4243460
oid=11511, datname=postgres, size=4324580
oid=313780, datname=testdb, size=8183012
```

Structure host variables "absorb" as many columns as the structure as fields. Additional columns can be assigned to other host variables. For example, the above program could also be restructured like this, with the `size` variable outside the structure:

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef struct
    {
       int oid;
       char datname[65];
    } dbinfo_t;

    dbinfo_t dbval;
    long long int size;
EXEC SQL END DECLARE SECTION;

    memset(&dbval, 0, sizeof(dbinfo_t));

    EXEC SQL DECLARE cur1 CURSOR FOR SELECT oid, datname, pg_database_size(oid) AS size
    EXEC SQL OPEN cur1;

    /* when end of result set reached, break out of while loop */
    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
        /* Fetch multiple columns into one structure. */
        EXEC SQL FETCH FROM cur1 INTO :dbval, :size;

        /* Print members of the structure. */
        printf("oid=%d, datname=%s, size=%lld\n", dbval.oid, dbval.datname, size);
    }

    EXEC SQL CLOSE cur1;
```

33.4.4.3.3. Typedefs

Use the `typedef` keyword to map new types to already existing types.

```
EXEC SQL BEGIN DECLARE SECTION;
    typedef char mychartype[40];
    typedef long serial_t;
EXEC SQL END DECLARE SECTION;
```

Note that you could also use:

```
EXEC SQL TYPE serial_t IS long;
```

This declaration does not need to be part of a declare section.

33.4.4.3.4. Pointers

You can declare pointers to the most common types. Note however that you cannot use pointers as target variables of queries without auto-allocation. See Section 33.7 for more information on auto-allocation.

```
EXEC SQL BEGIN DECLARE SECTION;
    int   *intp;
    char **charp;
EXEC SQL END DECLARE SECTION;
```

33.4.5. Handling Nonprimitive SQL Data Types

This section contains information on how to handle nonscalar and user-defined SQL-level data types in ECPG applications. Note that this is distinct from the handling of host variables of nonprimitive types, described in the previous section.

33.4.5.1. Arrays

SQL-level arrays are not directly supported in ECPG. It is not possible to simply map an SQL array into a C array host variable. This will result in undefined behavior. Some workarounds exist, however.

If a query accesses *elements* of an array separately, then this avoids the use of arrays in ECPG. Then, a host variable with a type that can be mapped to the element type should be used. For example, if a column type is array of `integer`, a host variable of type `int` can be used. Also if the element type is `varchar` or `text`, a host variable of type `char[]` or `VARCHAR[]` can be used.

Here is an example. Assume the following table:

```
CREATE TABLE t3 (
    ii integer[]
);

testdb=> SELECT * FROM t3;
     ii
-------------
 {1,2,3,4,5}
(1 row)
```

The following example program retrieves the 4th element of the array and stores it into a host variable of type `int`:

```
EXEC SQL BEGIN DECLARE SECTION;
int ii;
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[4] FROM t3;
EXEC SQL OPEN cur1;
```

```
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :ii ;
    printf("ii=%d\n", ii);
}

EXEC SQL CLOSE cur1;
```

This example shows the following result:

```
ii=4
```

To map multiple array elements to the multiple elements in an array type host variables each element of array column and each element of the host variable array have to be managed separately, for example:

```
EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii[1], ii[2], ii[3], ii[4] FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH FROM cur1 INTO :ii_a[0], :ii_a[1], :ii_a[2], :ii_a[3];
    ...
}
```

Note again that

```
EXEC SQL BEGIN DECLARE SECTION;
int ii_a[8];
EXEC SQL END DECLARE SECTION;

EXEC SQL DECLARE cur1 CURSOR FOR SELECT ii FROM t3;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* WRONG */
    EXEC SQL FETCH FROM cur1 INTO :ii_a;
    ...
}
```

would not work correctly in this case, because you cannot map an array type column to an array host variable directly.

Another workaround is to store arrays in their external string representation in host variables of type `char[]` or `VARCHAR[]`. For more details about this representation, see Section 8.15.2. Note that this means that the array cannot be accessed naturally as an array in the host program (without further processing that parses the text representation).

33.4.5.2. Composite Types

Composite types are not directly supported in ECPG, but an easy workaround is possible. The available workarounds are similar to the ones described for arrays above: Either access each attribute separately or use the external string representation.

For the following examples, assume the following type and table:

```
CREATE TYPE comp_t AS (intval integer, textval varchar(32));
CREATE TABLE t4 (compval comp_t);
INSERT INTO t4 VALUES ( (256, 'PostgreSQL') );
```

The most obvious solution is to access each attribute separately. The following program retrieves data from the example table by selecting each attribute of the type `comp_t` separately:

```
EXEC SQL BEGIN DECLARE SECTION;
int intval;
varchar textval[33];
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT list. */
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).intval, (compval).textval FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Fetch each element of the composite type column into host variables. */
    EXEC SQL FETCH FROM cur1 INTO :intval, :textval;

    printf("intval=%d, textval=%s\n", intval, textval.arr);
}

EXEC SQL CLOSE cur1;
```

To enhance this example, the host variables to store values in the `FETCH` command can be gathered into one structure. For more details about the host variable in the structure form, see Section 33.4.4.3.2. To switch to the structure, the example can be modified as below. The two host variables, `intval` and `textval`, become members of the `comp_t` structure, and the structure is specified on the `FETCH` command.

```
EXEC SQL BEGIN DECLARE SECTION;
typedef struct
{
    int intval;
    varchar textval[33];
} comp_t;
```

```
comp_t compval;
EXEC SQL END DECLARE SECTION;

/* Put each element of the composite type column in the SELECT list. */
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).intval, (compval).textval FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM cur1 INTO :compval;

    printf("intval=%d, textval=%s\n", compval.intval, compval.textval.arr);
}

EXEC SQL CLOSE cur1;
```

Although a structure is used in the `FETCH` command, the attribute names in the `SELECT` clause are specified one by one. This can be enhanced by using a `*` to ask for all attributes of the composite type value.

```
...
EXEC SQL DECLARE cur1 CURSOR FOR SELECT (compval).* FROM t4;
EXEC SQL OPEN cur1;

EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    /* Put all values in the SELECT list into one structure. */
    EXEC SQL FETCH FROM cur1 INTO :compval;

    printf("intval=%d, textval=%s\n", compval.intval, compval.textval.arr);
}
...
```

This way, composite types can be mapped into structures almost seamlessly, even though ECPG does not understand the composite type itself.

Finally, it is also possible to store composite type values in their external string representation in host variables of type `char[]` or `VARCHAR[]`. But that way, it is not easily possible to access the fields of the value from the host program.

33.4.5.3. User-defined Base Types

New user-defined base types are not directly supported by ECPG. You can use the external string representation and host variables of type `char[]` or `VARCHAR[]`, and this solution is indeed appropriate and sufficient for many types.

Here is an example using the data type `complex` from the example in Section 35.11. The external string representation of that type is `(%lf,%lf)`, which is defined in the functions `complex_in()` and `complex_out()` functions in Section 35.11. The following example inserts the complex type values `(1,1)` and `(3,3)` into the columns `a` and `b`, and select them from the table after that.

```
EXEC SQL BEGIN DECLARE SECTION;
    varchar a[64];
    varchar b[64];
EXEC SQL END DECLARE SECTION;

    EXEC SQL INSERT INTO test_complex VALUES ('(1,1)', '(3,3)');

    EXEC SQL DECLARE cur1 CURSOR FOR SELECT a, b FROM test_complex;
    EXEC SQL OPEN cur1;

    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
        EXEC SQL FETCH FROM cur1 INTO :a, :b;
        printf("a=%s, b=%s\n", a.arr, b.arr);
    }

    EXEC SQL CLOSE cur1;
```

This example shows following result:

```
a=(1,1), b=(3,3)
```

Another workaround is avoiding the direct use of the user-defined types in ECPG and instead create a function or cast that converts between the user-defined type and a primitive type that ECPG can handle. Note, however, that type casts, especially implicit ones, should be introduced into the type system very carefully.

For example,

```
CREATE FUNCTION create_complex(r double, i double) RETURNS complex
LANGUAGE SQL
IMMUTABLE
AS $$ SELECT $1 * complex '(1,0)' + $2 * complex '(0,1)' $$;
```

After this definition, the following

```
EXEC SQL BEGIN DECLARE SECTION;
double a, b, c, d;
EXEC SQL END DECLARE SECTION;

a = 1;
b = 2;
c = 3;
d = 4;

EXEC SQL INSERT INTO test_complex VALUES (create_complex(:a, :b), create_complex(:c, :d)
```

has the same effect as

```
EXEC SQL INSERT INTO test_complex VALUES ('(1,2)', '(3,4)');
```

33.4.6. Indicators

The examples above do not handle null values. In fact, the retrieval examples will raise an error if they fetch a null value from the database. To be able to pass null values to the database or retrieve null values from the database, you need to append a second host variable specification to each host variable that contains data. This second host variable is called the *indicator* and contains a flag that tells whether the datum is null, in which case the value of the real host variable is ignored. Here is an example that handles the retrieval of null values correctly:

```
EXEC SQL BEGIN DECLARE SECTION;
VARCHAR val;
int val_ind;
EXEC SQL END DECLARE SECTION:

 ...

EXEC SQL SELECT b INTO :val :val_ind FROM test1;
```

The indicator variable `val_ind` will be zero if the value was not null, and it will be negative if the value was null.

The indicator has another function: if the indicator value is positive, it means that the value is not null, but it was truncated when it was stored in the host variable.

If the argument `-r no_indicator` is passed to the preprocessor `ecpg`, it works in "no-indicator" mode. In no-indicator mode, if no indicator variable is specified, null values are signaled (on input and output) for character string types as empty string and for integer types as the lowest possible value for type (for example, `INT_MIN` for `int`).

33.5. Dynamic SQL

In many cases, the particular SQL statements that an application has to execute are known at the time the application is written. In some cases, however, the SQL statements are composed at run time or provided by an external source. In these cases you cannot embed the SQL statements directly into the C source code, but there is a facility that allows you to call arbitrary SQL statements that you provide in a string variable.

33.5.1. Executing Statements without a Result Set

The simplest way to execute an arbitrary SQL statement is to use the command `EXECUTE IMMEDIATE`. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "CREATE TABLE test1 (...);";
EXEC SQL END DECLARE SECTION;

EXEC SQL EXECUTE IMMEDIATE :stmt;
```

`EXECUTE IMMEDIATE` can be used for SQL statements that do not return a result set (e.g., DDL, `INSERT`, `UPDATE`, `DELETE`). You cannot execute statements that retrieve data (e.g., `SELECT`) this way. The next section describes how to do that.

33.5.2. Executing a Statement with Input Parameters

A more powerful way to execute arbitrary SQL statements is to prepare them once and execute the prepared statement as often as you like. It is also possible to prepare a generalized version of a statement and then execute specific versions of it by substituting parameters. When preparing the statement, write question marks where you want to substitute parameters later. For example:

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "INSERT INTO test1 VALUES(?, ?);";
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
 ...
EXEC SQL EXECUTE mystmt USING 42, 'foobar';
```

When you don't need the prepared statement anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE PREPARE name;
```

33.5.3. Executing a Statement with a Result Set

To execute an SQL statement with a single result row, `EXECUTE` can be used. To save the result, add an `INTO` clause.

```
EXEC SQL BEGIN DECLARE SECTION;
const char *stmt = "SELECT a, b, c FROM test1 WHERE a > ?";
int v1, v2;
VARCHAR v3[50];
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE mystmt FROM :stmt;
 ...
EXEC SQL EXECUTE mystmt INTO :v1, :v2, :v3 USING 37;
```

An `EXECUTE` command can have an `INTO` clause, a `USING` clause, both, or neither.

If a query is expected to return more than one result row, a cursor should be used, as in the following example. (See Section 33.3.2 for more details about the cursor.)

```
EXEC SQL BEGIN DECLARE SECTION;
char dbaname[128];
char datname[128];
char *stmt = "SELECT u.usename as dbaname, d.datname "
             "  FROM pg_database d, pg_user u "
             "  WHERE d.datdba = u.usesysid";
EXEC SQL END DECLARE SECTION;

EXEC SQL CONNECT TO testdb AS con1 USER testuser;

EXEC SQL PREPARE stmt1 FROM :stmt;

EXEC SQL DECLARE cursor1 CURSOR FOR stmt1;
EXEC SQL OPEN cursor1;
```

```
EXEC SQL WHENEVER NOT FOUND DO BREAK;

while (1)
{
    EXEC SQL FETCH cursor1 INTO :dbaname,:datname;
    printf("dbaname=%s, datname=%s\n", dbaname, datname);
}

EXEC SQL CLOSE cursor1;

EXEC SQL COMMIT;
EXEC SQL DISCONNECT ALL;
```

33.6. pgtypes Library

The pgtypes library maps PostgreSQL database types to C equivalents that can be used in C programs. It also offers functions to do basic calculations with those types within C, i.e., without the help of the PostgreSQL server. See the following example:

```
EXEC SQL BEGIN DECLARE SECTION;
   date date1;
   timestamp ts1, tsout;
   interval iv1;
   char *out;
EXEC SQL END DECLARE SECTION;

PGTYPESdate_today(&date1);
EXEC SQL SELECT started, duration INTO :ts1, :iv1 FROM datetbl WHERE d=:date1;
PGTYPEStimestamp_add_interval(&ts1, &iv1, &tsout);
out = PGTYPEStimestamp_to_asc(&tsout);
printf("Started + duration: %s\n", out);
free(out);
```

33.6.1. The numeric Type

The numeric type offers to do calculations with arbitrary precision. See Section 8.1 for the equivalent type in the PostgreSQL server. Because of the arbitrary precision this variable needs to be able to expand and shrink dynamically. That's why you can only create numeric variables on the heap, by means of the `PGTYPESnumeric_new` and `PGTYPESnumeric_free` functions. The decimal type, which is similar but limited in precision, can be created on the stack as well as on the heap.

The following functions can be used to work with the numeric type:

`PGTYPESnumeric_new`

Request a pointer to a newly allocated numeric variable.

```
numeric *PGTYPESnumeric_new(void);
```

`PGTYPESnumeric_free`

Free a numeric type, release all of its memory.

```
void PGTYPESnumeric_free(numeric *var);
```

`PGTYPESnumeric_from_asc`

Parse a numeric type from its string notation.

```
numeric *PGTYPESnumeric_from_asc(char *str, char **endptr);
```

Valid formats are for example: `-2`, `.794`, `+3.44`, `592.49E07` or `-32.84e-4`. If the value could be parsed successfully, a valid pointer is returned, else the NULL pointer. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

`PGTYPESnumeric_to_asc`

Returns a pointer to a string allocated by `malloc` that contains the string representation of the numeric type `num`.

```
char *PGTYPESnumeric_to_asc(numeric *num, int dscale);
```

The numeric value will be printed with `dscale` decimal digits, with rounding applied if necessary.

`PGTYPESnumeric_add`

Add two numeric variables into a third one.

```
int PGTYPESnumeric_add(numeric *var1, numeric *var2, numeric *result);
```

The function adds the variables `var1` and `var2` into the result variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_sub`

Subtract two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_sub(numeric *var1, numeric *var2, numeric *result);
```

The function subtracts the variable `var2` from the variable `var1`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_mul`

Multiply two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_mul(numeric *var1, numeric *var2, numeric *result);
```

The function multiplies the variables `var1` and `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_div`

Divide two numeric variables and return the result in a third one.

```
int PGTYPESnumeric_div(numeric *var1, numeric *var2, numeric *result);
```

The function divides the variables `var1` by `var2`. The result of the operation is stored in the variable `result`. The function returns 0 on success and -1 in case of error.

`PGTYPESnumeric_cmp`

Compare two numeric variables.

```
int PGTYPESnumeric_cmp(numeric *var1, numeric *var2)
```

This function compares two numeric variables. In case of error, `INT_MAX` is returned. On success, the function returns one of three possible results:

- 1, if `var1` is bigger than `var2`
- -1, if `var1` is smaller than `var2`

- 0, if `var1` and `var2` are equal

`PGTYPESnumeric_from_int`

Convert an int variable to a numeric variable.

```
int PGTYPESnumeric_from_int(signed int int_val, numeric *var);
```

This function accepts a variable of type signed int and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

`PGTYPESnumeric_from_long`

Convert a long int variable to a numeric variable.

```
int PGTYPESnumeric_from_long(signed long int long_val, numeric *var);
```

This function accepts a variable of type signed long int and stores it in the numeric variable `var`. Upon success, 0 is returned and -1 in case of a failure.

`PGTYPESnumeric_copy`

Copy over one numeric variable into another one.

```
int PGTYPESnumeric_copy(numeric *src, numeric *dst);
```

This function copies over the value of the variable that `src` points to into the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

`PGTYPESnumeric_from_double`

Convert a variable of type double to a numeric.

```
int  PGTYPESnumeric_from_double(double d, numeric *dst);
```

This function accepts a variable of type double and stores the result in the variable that `dst` points to. It returns 0 on success and -1 if an error occurs.

`PGTYPESnumeric_to_double`

Convert a variable of type numeric to double.

```
int PGTYPESnumeric_to_double(numeric *nv, double *dp)
```

The function converts the numeric value from the variable that `nv` points to into the double variable that `dp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_int`

Convert a variable of type numeric to int.

```
int PGTYPESnumeric_to_int(numeric *nv, int *ip);
```

The function converts the numeric value from the variable that `nv` points to into the integer variable that `ip` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_long`

Convert a variable of type numeric to long.

```
int PGTYPESnumeric_to_long(numeric *nv, long *lp);
```

The function converts the numeric value from the variable that `nv` points to into the long integer variable that `lp` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_to_decimal`

Convert a variable of type numeric to decimal.

```
int PGTYPESnumeric_to_decimal(numeric *src, decimal *dst);
```

The function converts the numeric value from the variable that `src` points to into the decimal variable that `dst` points to. It returns 0 on success and -1 if an error occurs, including overflow. On overflow, the global variable `errno` will be set to `PGTYPES_NUM_OVERFLOW` additionally.

`PGTYPESnumeric_from_decimal`

Convert a variable of type decimal to numeric.

```
int PGTYPESnumeric_from_decimal(decimal *src, numeric *dst);
```

The function converts the decimal value from the variable that `src` points to into the numeric variable that `dst` points to. It returns 0 on success and -1 if an error occurs. Since the decimal type is implemented as a limited version of the numeric type, overflow cannot occur with this conversion.

33.6.2. The date Type

The date type in C enables your programs to deal with data of the SQL type date. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the date type:

`PGTYPESdate_from_timestamp`

Extract the date part from a timestamp.

```
date PGTYPESdate_from_timestamp(timestamp dt);
```

The function receives a timestamp as its only argument and returns the extracted date part from this timestamp.

`PGTYPESdate_from_asc`

Parse a date from its textual representation.

```
date PGTYPESdate_from_asc(char *str, char **endptr);
```

The function receives a C char* string `str` and a pointer to a C char* string `endptr`. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

Note that the function always assumes MDY-formatted dates and there is currently no variable to change that within ECPG.

Table 33-2 shows the allowed input formats.

Table 33-2. Valid Input Formats for `PGTYPESdate_from_asc`

Input	Result
`January 8, 1999`	`January 8, 1999`
`1999-01-08`	`January 8, 1999`
`1/8/1999`	`January 8, 1999`
`1/18/1999`	`January 18, 1999`
`01/02/03`	`February 1, 2003`
`1999-Jan-08`	`January 8, 1999`
`Jan-08-1999`	`January 8, 1999`
`08-Jan-1999`	`January 8, 1999`
`99-Jan-08`	`January 8, 1999`

Input	Result
08-Jan-99	January 8, 1999
08-Jan-06	January 8, 2006
Jan-08-99	January 8, 1999
19990108	ISO 8601; January 8, 1999
990108	ISO 8601; January 8, 1999
1999.008	year and day of year
J2451187	Julian day
January 8, 99 BC	year 99 before the Common Era

`PGTYPESdate_to_asc`

Return the textual representation of a date variable.

```
char *PGTYPESdate_to_asc(date dDate);
```

The function receives the date `dDate` as its only parameter. It will output the date in the form `1999-01-18`, i.e., in the `YYYY-MM-DD` format.

`PGTYPESdate_julmdy`

Extract the values for the day, the month and the year from a variable of type date.

```
void PGTYPESdate_julmdy(date d, int *mdy);
```

The function receives the date `d` and a pointer to an array of 3 integer values `mdy`. The variable name indicates the sequential order: `mdy[0]` will be set to contain the number of the month, `mdy[1]` will be set to the value of the day and `mdy[2]` will contain the year.

`PGTYPESdate_mdyjul`

Create a date value from an array of 3 integers that specify the day, the month and the year of the date.

```
void PGTYPESdate_mdyjul(int *mdy, date *jdate);
```

The function receives the array of the 3 integers (`mdy`) as its first argument and as its second argument a pointer to a variable of type date that should hold the result of the operation.

`PGTYPESdate_dayofweek`

Return a number representing the day of the week for a date value.

```
int PGTYPESdate_dayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday
- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday
- 6 - Saturday

`PGTYPESdate_today`

Get the current date.

```
void PGTYPESdate_today(date *d);
```

The function receives a pointer to a date variable (`d`) that it sets to the current date.

`PGTYPESdate_fmt_asc`

Convert a variable of type date to its textual representation using a format mask.

```
int PGTYPESdate_fmt_asc(date dDate, char *fmtstring, char *outbuf);
```

The function receives the date to convert (`dDate`), the format mask (`fmtstring`) and the string that will hold the textual representation of the date (`outbuf`).

On success, 0 is returned and a negative value if an error occurred.

The following literals are the field specifiers you can use:

- `dd` - The number of the day of the month.
- `mm` - The number of the month of the year.
- `yy` - The number of the year as a two digit number.
- `yyyy` - The number of the year as a four digit number.
- `ddd` - The name of the day (abbreviated).
- `mmm` - The name of the month (abbreviated).

All other characters are copied 1:1 to the output string.

Table 33-3 indicates a few possible formats. This will give you an idea of how to use this function. All output lines are based on the same date: November 23, 1959.

Table 33-3. Valid Input Formats for `PGTYPESdate_fmt_asc`

Format	Result
mmddyy	112359
ddmmyy	231159
yymmdd	591123
yy/mm/dd	59/11/23
yy mm dd	59 11 23
yy.mm.dd	59.11.23
.mm.yyyy.dd.	.11.1959.23.
mmm. dd, yyyy	Nov. 23, 1959
mmm dd yyyy	Nov 23 1959
yyyy dd mm	1959 23 11
ddd, mmm. dd, yyyy	Mon, Nov. 23, 1959
(ddd) mmm. dd, yyyy	(Mon) Nov. 23, 1959

`PGTYPESdate_defmt_asc`

Use a format mask to convert a C `char*` string to a value of type date.

```
int PGTYPESdate_defmt_asc(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (`d`), the format mask to use for parsing the date (`fmt`) and the C char* string containing the textual representation of the date (`str`). The textual representation is expected to match the format mask.

However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals `yy` or `yyyy` that indicate the position of the year, `mm` to indicate the position of the month and `dd` to indicate the position of the day.

Table 33-4 indicates a few possible formats. This will give you an idea of how to use this function.

Table 33-4. Valid Input Formats for `rdefmtdate`

Format	String	Result
ddmmyy	21-2-54	1954-02-21
ddmmyy	2-12-54	1954-12-02
ddmmyy	20111954	1954-11-20
ddmmyy	130464	1964-04-13
mmm.dd.yyyy	MAR-12-1967	1967-03-12
yy/mm/dd	1954, February 3rd	1954-02-03
mmm.dd.yyyy	041269	1969-04-12
yy/mm/dd	In the year 2525, in the month of July, mankind will be alive on the 28th day	2525-07-28
dd-mm-yy	I said on the 28th of July in the year 2525	2525-07-28
mmm.dd.yyyy	9/14/58	1958-09-14
yy/mm/dd	47/03/29	1947-03-29
mmm.dd.yyyy	oct 28 1975	1975-10-28
mmddyy	Nov 14th, 1985	1985-11-14

33.6.3. The timestamp Type

The timestamp type in C enables your programs to deal with data of the SQL type timestamp. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the timestamp type:

`PGTYPEStimestamp_from_asc`

Parse a timestamp from its textual representation into a timestamp variable.

```
timestamp PGTYPEStimestamp_from_asc(char *str, char **endptr);
```

The function receives the string to parse (`str`) and a pointer to a C char* (`endptr`). At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

The function returns the parsed timestamp on success. On error, `PGTYPESInvalidTimestamp` is returned and `errno` is set to `PGTYPES_TS_BAD_TIMESTAMP`. See *`PGTYPESInvalidTimestamp`* for important notes on this value.

In general, the input string can contain any combination of an allowed date specification, a whitespace character and an allowed time specification. Note that time zones are not supported

by ECPG. It can parse them but does not apply any calculation as the PostgreSQL server does for example. Timezone specifiers are silently discarded.

Table 33-5 contains a few examples for input strings.

Table 33-5. Valid Input Formats for `PGTYPEStimestamp_from_asc`

Input	Result
`1999-01-08 04:05:06`	`1999-01-08 04:05:06`
`January 8 04:05:06 1999 PST`	`1999-01-08 04:05:06`
`1999-Jan-08 04:05:06.789-8`	`1999-01-08 04:05:06.789 (time zone specifier ignored)`
`J2451187 04:05-08:00`	`1999-01-08 04:05:00 (time zone specifier ignored)`

`PGTYPEStimestamp_to_asc`

Converts a date to a C char* string.

```
char *PGTYPEStimestamp_to_asc(timestamp tstamp);
```

The function receives the timestamp `tstamp` as its only argument and returns an allocated string that contains the textual representation of the timestamp.

`PGTYPEStimestamp_current`

Retrieve the current timestamp.

```
void PGTYPEStimestamp_current(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that `ts` points to.

`PGTYPEStimestamp_fmt_asc`

Convert a timestamp variable to a C char* using a format mask.

```
int PGTYPEStimestamp_fmt_asc(timestamp *ts, char *output, int str_len, char *fmtstr),
```

The function receives a pointer to the timestamp to convert as its first argument (`ts`), a pointer to the output buffer (`output`), the maximal length that has been allocated for the output buffer (`str_len`) and the format mask to use for the conversion (`fmtstr`).

Upon success, the function returns 0 and a negative value if an error occurred.

You can use the following format specifiers for the format mask. The format specifiers are the same ones that are used in the `strftime` function in libc. Any non-format specifier will be copied into the output buffer.

- `%A` - is replaced by national representation of the full weekday name.
- `%a` - is replaced by national representation of the abbreviated weekday name.
- `%B` - is replaced by national representation of the full month name.
- `%b` - is replaced by national representation of the abbreviated month name.
- `%C` - is replaced by (year / 100) as decimal number; single digits are preceded by a zero.
- `%c` - is replaced by national representation of time and date.
- `%D` - is equivalent to `%m/%d/%y`.
- `%d` - is replaced by the day of the month as a decimal number (01-31).

- `%E* %O*` - POSIX locale extensions. The sequences `%Ec %EC %Ex %EX %Ey %EY %Od %Oe %OH %OI %Om %OM %OS %Ou %OU %OV %Ow %OW %Oy` are supposed to provide alternative representations.

  Additionally `%OB` implemented to represent alternative months names (used standalone, without day mentioned).

- `%e` - is replaced by the day of month as a decimal number (1-31); single digits are preceded by a blank.
- `%F` - is equivalent to `%Y-%m-%d`.
- `%G` - is replaced by a year as a decimal number with century. This year is the one that contains the greater part of the week (Monday as the first day of the week).
- `%g` - is replaced by the same year as in `%G`, but as a decimal number without century (00-99).
- `%H` - is replaced by the hour (24-hour clock) as a decimal number (00-23).
- `%h` - the same as `%b`.
- `%I` - is replaced by the hour (12-hour clock) as a decimal number (01-12).
- `%j` - is replaced by the day of the year as a decimal number (001-366).
- `%k` - is replaced by the hour (24-hour clock) as a decimal number (0-23); single digits are preceded by a blank.
- `%l` - is replaced by the hour (12-hour clock) as a decimal number (1-12); single digits are preceded by a blank.
- `%M` - is replaced by the minute as a decimal number (00-59).
- `%m` - is replaced by the month as a decimal number (01-12).
- `%n` - is replaced by a newline.
- `%O*` - the same as `%E*`.
- `%p` - is replaced by national representation of either “ante meridiem” or “post meridiem” as appropriate.
- `%R` - is equivalent to `%H:%M`.
- `%r` - is equivalent to `%I:%M:%S %p`.
- `%S` - is replaced by the second as a decimal number (00-60).
- `%s` - is replaced by the number of seconds since the Epoch, UTC.
- `%T` - is equivalent to `%H:%M:%S`
- `%t` - is replaced by a tab.
- `%U` - is replaced by the week number of the year (Sunday as the first day of the week) as a decimal number (00-53).
- `%u` - is replaced by the weekday (Monday as the first day of the week) as a decimal number (1-7).
- `%V` - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (01-53). If the week containing January 1 has four or more days in the new year, then it is week 1; otherwise it is the last week of the previous year, and the next week is week 1.
- `%v` - is equivalent to `%e-%b-%Y`.

- %W - is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (00-53).
- %w - is replaced by the weekday (Sunday as the first day of the week) as a decimal number (0-6).
- %X - is replaced by national representation of the time.
- %x - is replaced by national representation of the date.
- %Y - is replaced by the year with century as a decimal number.
- %y - is replaced by the year without century as a decimal number (00-99).
- %Z - is replaced by the time zone name.
- %z - is replaced by the time zone offset from UTC; a leading plus sign stands for east of UTC, a minus sign for west of UTC, hours and minutes follow with two digits each and no delimiter between them (common form for RFC 822 date headers).
- %+ - is replaced by national representation of the date and time.
- %-* - GNU libc extension. Do not do any padding when performing numerical outputs.
- $_* - GNU libc extension. Explicitly specify space for padding.
- %0* - GNU libc extension. Explicitly specify zero for padding.
- %% - is replaced by %.

PGTYPESTimestamp_sub

Subtract one timestamp from another one and save the result in a variable of type interval.

```
int PGTYPESTimestamp_sub(timestamp *ts1, timestamp *ts2, interval *iv);
```

The function will subtract the timestamp variable that ts2 points to from the timestamp variable that ts1 points to and will store the result in the interval variable that iv points to.

Upon success, the function returns 0 and a negative value if an error occurred.

PGTYPESTimestamp_defmt_asc

Parse a timestamp value from its textual representation using a formatting mask.

```
int PGTYPESTimestamp_defmt_asc(char *str, char *fmt, timestamp *d);
```

The function receives the textual representation of a timestamp in the variable str as well as the formatting mask to use in the variable fmt. The result will be stored in the variable that d points to.

If the formatting mask fmt is NULL, the function will fall back to the default formatting mask which is %Y-%m-%d %H:%M:%S.

This is the reverse function to *PGTYPESTimestamp_fmt_asc*. See the documentation there in order to find out about the possible formatting mask entries.

PGTYPESTimestamp_add_interval

Add an interval variable to a timestamp variable.

```
int PGTYPESTimestamp_add_interval(timestamp *tin, interval *span, timestamp *tout);
```

The function receives a pointer to a timestamp variable tin and a pointer to an interval variable span. It adds the interval to the timestamp and saves the resulting timestamp in the variable that tout points to.

Upon success, the function returns 0 and a negative value if an error occurred.

`PGTYPEStimestamp_sub_interval`

Subtract an interval variable from a timestamp variable.

```
int PGTYPEStimestamp_sub_interval(timestamp *tin, interval *span, timestamp *tout);
```

The function subtracts the interval variable that `span` points to from the timestamp variable that `tin` points to and saves the result into the variable that `tout` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

33.6.4. The interval Type

The interval type in C enables your programs to deal with data of the SQL type interval. See Section 8.5 for the equivalent type in the PostgreSQL server.

The following functions can be used to work with the interval type:

`PGTYPESinterval_new`

Return a pointer to a newly allocated interval variable.

```
interval *PGTYPESinterval_new(void);
```

`PGTYPESinterval_free`

Release the memory of a previously allocated interval variable.

```
void PGTYPESinterval_new(interval *intvl);
```

`PGTYPESinterval_from_asc`

Parse an interval from its textual representation.

```
interval *PGTYPESinterval_from_asc(char *str, char **endptr);
```

The function parses the input string `str` and returns a pointer to an allocated interval variable. At the moment ECPG always parses the complete string and so it currently does not support to store the address of the first invalid character in `*endptr`. You can safely set `endptr` to NULL.

`PGTYPESinterval_to_asc`

Convert a variable of type interval to its textual representation.

```
char *PGTYPESinterval_to_asc(interval *span);
```

The function converts the interval variable that `span` points to into a C char*. The output looks like this example: `@ 1 day 12 hours 59 mins 10 secs.`

`PGTYPESinterval_copy`

Copy a variable of type interval.

```
int PGTYPESinterval_copy(interval *intvlsrc, interval *intvldest);
```

The function copies the interval variable that `intvlsrc` points to into the variable that `intvldest` points to. Note that you need to allocate the memory for the destination variable before.

33.6.5. The decimal Type

The decimal type is similar to the numeric type. However it is limited to a maximum precision of 30 significant digits. In contrast to the numeric type which can be created on the heap only,

the decimal type can be created either on the stack or on the heap (by means of the functions PGTYPESdecimal_new and PGTYPESdecimal_free). There are a lot of other functions that deal with the decimal type in the Informix compatibility mode described in Section 33.15.

The following functions can be used to work with the decimal type and are not only contained in the libcompat library.

PGTYPESdecimal_new

Request a pointer to a newly allocated decimal variable.

```
decimal *PGTYPESdecimal_new(void);
```

PGTYPESdecimal_free

Free a decimal type, release all of its memory.

```
void PGTYPESdecimal_free(decimal *var);
```

33.6.6. errno Values of pgtypeslib

PGTYPES_NUM_BAD_NUMERIC

An argument should contain a numeric variable (or point to a numeric variable) but in fact its in-memory representation was invalid.

PGTYPES_NUM_OVERFLOW

An overflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause overflow.

PGTYPES_NUM_UNDERFLOW

An underflow occurred. Since the numeric type can deal with almost arbitrary precision, converting a numeric variable into other types might cause underflow.

PGTYPES_NUM_DIVIDE_ZERO

A division by zero has been attempted.

PGTYPES_DATE_BAD_DATE

An invalid date string was passed to the PGTYPESdate_from_asc function.

PGTYPES_DATE_ERR_EARGS

Invalid arguments were passed to the PGTYPESdate_defmt_asc function.

PGTYPES_DATE_ERR_ENOSHORTDATE

An invalid token in the input string was found by the PGTYPESdate_defmt_asc function.

PGTYPES_INTVL_BAD_INTERVAL

An invalid interval string was passed to the PGTYPESinterval_from_asc function, or an invalid interval value was passed to the PGTYPESinterval_to_asc function.

PGTYPES_DATE_ERR_ENOTDMY

There was a mismatch in the day/month/year assignment in the PGTYPESdate_defmt_asc function.

`PGTYPES_DATE_BAD_DAY`

An invalid day of the month value was found by the `PGTYPESdate_defmt_asc` function.

`PGTYPES_DATE_BAD_MONTH`

An invalid month value was found by the `PGTYPESdate_defmt_asc` function.

`PGTYPES_TS_BAD_TIMESTAMP`

An invalid timestamp string pass passed to the `PGTYPEStimestamp_from_asc` function, or an invalid timestamp value was passed to the `PGTYPEStimestamp_to_asc` function.

`PGTYPES_TS_ERR_EINFTIME`

An infinite timestamp value was encountered in a context that cannot handle it.

33.6.7. Special Constants of pgtypeslib

`PGTYPESInvalidTimestamp`

A value of type timestamp representing an invalid time stamp. This is returned by the function `PGTYPEStimestamp_from_asc` on parse error. Note that due to the internal representation of the `timestamp` data type, `PGTYPESInvalidTimestamp` is also a valid timestamp at the same time. It is set to `1899-12-31 23:59:59`. In order to detect errors, make sure that your application does not only test for `PGTYPESInvalidTimestamp` but also for `errno != 0` after each call to `PGTYPEStimestamp_from_asc`.

33.7. Using Descriptor Areas

An SQL descriptor area is a more sophisticated method for processing the result of a `SELECT`, `FETCH` or a `DESCRIBE` statement. An SQL descriptor area groups the data of one row of data together with metadata items into one data structure. The metadata is particularly useful when executing dynamic SQL statements, where the nature of the result columns might not be known ahead of time. PostgreSQL provides two ways to use Descriptor Areas: the named SQL Descriptor Areas and the C-structure SQLDAs.

33.7.1. Named SQL Descriptor Areas

A named SQL descriptor area consists of a header, which contains information concerning the entire descriptor, and one or more item descriptor areas, which basically each describe one column in the result row.

Before you can use an SQL descriptor area, you need to allocate one:

```
EXEC SQL ALLOCATE DESCRIPTOR identifier;
```

The identifier serves as the "variable name" of the descriptor area. When you don't need the descriptor anymore, you should deallocate it:

```
EXEC SQL DEALLOCATE DESCRIPTOR identifier;
```

To use a descriptor area, specify it as the storage target in an `INTO` clause, instead of listing host variables:

```
EXEC SQL FETCH NEXT FROM mycursor INTO SQL DESCRIPTOR mydesc;
```

If the result set is empty, the Descriptor Area will still contain the metadata from the query, i.e. the field names.

For not yet executed prepared queries, the `DESCRIBE` statement can be used to get the metadata of the result set:

```
EXEC SQL BEGIN DECLARE SECTION;
char *sql_stmt = "SELECT * FROM table1";
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE stmt1 FROM :sql_stmt;
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;
```

Before PostgreSQL 9.0, the `SQL` keyword was optional, so using `DESCRIPTOR` and `SQL DESCRIPTOR` produced named SQL Descriptor Areas. Now it is mandatory, omitting the `SQL` keyword produces SQLDA Descriptor Areas, see Section 33.7.2.

In `DESCRIBE` and `FETCH` statements, the `INTO` and `USING` keywords can be used to similarly: they produce the result set and the metadata in a Descriptor Area.

Now how do you get the data out of the descriptor area? You can think of the descriptor area as a structure with named fields. To retrieve the value of a field from the header and store it into a host variable, use the following command:

```
EXEC SQL GET DESCRIPTOR name :hostvar = field;
```

Currently, there is only one header field defined: *`COUNT`*, which tells how many item descriptor areas exist (that is, how many columns are contained in the result). The host variable needs to be of an integer type. To get a field from the item descriptor area, use the following command:

```
EXEC SQL GET DESCRIPTOR name VALUE num :hostvar = field;
```

`num` can be a literal integer or a host variable containing an integer. Possible fields are:

`CARDINALITY` (integer)

number of rows in the result set

`DATA`

actual data item (therefore, the data type of this field depends on the query)

`DATETIME_INTERVAL_CODE` (integer)

When `TYPE` is `9`, `DATETIME_INTERVAL_CODE` will have a value of `1` for `DATE`, `2` for `TIME`, `3` for `TIMESTAMP`, `4` for `TIME WITH TIME ZONE`, or `5` for `TIMESTAMP WITH TIME ZONE`.

`DATETIME_INTERVAL_PRECISION` (integer)

not implemented

`INDICATOR` (integer)

the indicator (indicating a null value or a value truncation)

`KEY_MEMBER` (integer)

not implemented

`LENGTH` (integer)

length of the datum in characters

`NAME` (string)

name of the column

`NULLABLE` (integer)

not implemented

`OCTET_LENGTH` (integer)

length of the character representation of the datum in bytes

`PRECISION` (integer)

precision (for type `numeric`)

`RETURNED_LENGTH` (integer)

length of the datum in characters

`RETURNED_OCTET_LENGTH` (integer)

length of the character representation of the datum in bytes

`SCALE` (integer)

scale (for type `numeric`)

`TYPE` (integer)

numeric code of the data type of the column

In `EXECUTE`, `DECLARE` and `OPEN` statements, the effect of the `INTO` and `USING` keywords are different. A Descriptor Area can also be manually built to provide the input parameters for a query or a cursor and `USING SQL DESCRIPTOR` *`name`* is the way to pass the input parameters into a parametrized query. The statement to build a named SQL Descriptor Area is below:

```
EXEC SQL SET DESCRIPTOR name VALUE num field = :hostvar;
```

PostgreSQL supports retrieving more that one record in one `FETCH` statement and storing the data in host variables in this case assumes that the variable is an array. E.g.:

```
EXEC SQL BEGIN DECLARE SECTION;
int id[5];
EXEC SQL END DECLARE SECTION;

EXEC SQL FETCH 5 FROM mycursor INTO SQL DESCRIPTOR mydesc;

EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :id = DATA;
```

33.7.2. SQLDA Descriptor Areas

An SQLDA Descriptor Area is a C language structure which can be also used to get the result set and the metadata of a query. One structure stores one record from the result set.

```
EXEC SQL include sqlda.h;
sqlda_t         *mysqlda;

EXEC SQL FETCH 3 FROM mycursor INTO DESCRIPTOR mysqlda;
```

Note that the `SQL` keyword is omitted. The paragraphs about the use cases of the `INTO` and `USING` keywords in Section 33.7.1 also apply here with an addition. In a `DESCRIBE` statement the `DESCRIPTOR` keyword can be completely omitted if the `INTO` keyword is used:

```
EXEC SQL DESCRIBE prepared_statement INTO mysqlda;
```

The general flow of a program that uses SQLDA is:

1. Prepare a query, and declare a cursor for it.
2. Declare an SQLDA for the result rows.
3. Declare an SQLDA for the input parameters, and initialize them (memory allocation, parameter settings).
4. Open a cursor with the input SQLDA.
5. Fetch rows from the cursor, and store them into an output SQLDA.
6. Read values from the output SQLDA into the host variables (with conversion if necessary).
7. Close the cursor.
8. Free the memory area allocated for the input SQLDA.

33.7.2.1. SQLDA Data Structure

SQLDA uses three data structure types: `sqlda_t`, `sqlvar_t`, and `struct sqlname`.

> **Tip:** PostgreSQL's SQLDA has a similar data structure to the one in IBM DB2 Universal Database, so some technical information on DB2's SQLDA could help understanding PostgreSQL's one better.

33.7.2.1.1. sqlda_t Structure

The structure type `sqlda_t` is the type of the actual SQLDA. It holds one record. And two or more `sqlda_t` structures can be connected in a linked list with the pointer in the `desc_next` field, thus representing an ordered collection of rows. So, when two or more rows are fetched, the application can read them by following the `desc_next` pointer in each `sqlda_t` node.

The definition of `sqlda_t` is:

```
struct sqlda_struct
{
    char            sqldaid[8];
    long            sqldabc;
```

```
    short           sqln;
    short           sqld;
    struct sqlda_struct *desc_next;
    struct sqlvar_struct sqlvar[1];
};

typedef struct sqlda_struct sqlda_t;
```

The meaning of the fields is:

`sqldaid`

It contains the literal string `"SQLDA "`.

`sqldabc`

It contains the size of the allocated space in bytes.

`sqln`

It contains the number of input parameters for a parametrized query case it's passed into `OPEN`, `DECLARE` or `EXECUTE` statements using the `USING` keyword. In case it's used as output of `SELECT`, `EXECUTE` or `FETCH` statements, its value is the same as `sqld` statement

`sqld`

It contains the number of fields in a result set.

`desc_next`

If the query returns more than one record, multiple linked SQLDA structures are returned, and `desc_next` holds a pointer to the next entry in the list.

`sqlvar`

This is the array of the columns in the result set.

33.7.2.1.2. sqlvar_t Structure

The structure type `sqlvar_t` holds a column value and metadata such as type and length. The definition of the type is:

```
struct sqlvar_struct
{
    short          sqltype;
    short          sqllen;
    char          *sqldata;
    short         *sqlind;
    struct sqlname sqlname;
};

typedef struct sqlvar_struct sqlvar_t;
```

The meaning of the fields is:

`sqltype`

Contains the type identifier of the field. For values, see `enum ECPGttype` in `ecpgtype.h`.

`sqllen`

Contains the binary length of the field. e.g. 4 bytes for `ECPGt_int`.

`sqldata`

Points to the data. The format of the data is described in Section 33.4.4.

`sqlind`

Points to the null indicator. 0 means not null, -1 means null.

`sqlname`

The name of the field.

33.7.2.1.3. struct sqlname Structure

A `struct sqlname` structure holds a column name. It is used as a member of the `sqlvar_t` structure. The definition of the structure is:

```
#define NAMEDATALEN 64

struct sqlname
{
        short           length;
        char            data[NAMEDATALEN];
};
```

The meaning of the fields is:

`length`

Contains the length of the field name.

`data`

Contains the actual field name.

33.7.2.2. Retrieving a Result Set Using an SQLDA

The general steps to retrieve a query result set through an SQLDA are:

1. Declare an `sqlda_t` structure to receive the result set.
2. Execute `FETCH`/`EXECUTE`/`DESCRIBE` commands to process a query specifying the declared SQLDA.
3. Check the number of records in the result set by looking at `sqln`, a member of the `sqlda_t` structure.
4. Get the values of each column from `sqlvar[0]`, `sqlvar[1]`, etc., members of the `sqlda_t` structure.
5. Go to next row (`sqlda_t` structure) by following the `desc_next` pointer, a member of the `sqlda_t` structure.

6. Repeat above as you need.

Here is an example retrieving a result set through an SQLDA.

First, declare a `sqlda_t` structure to receive the result set.

```
sqlda_t *sqlda1;
```

Next, specify the SQLDA in a command. This is a `FETCH` command example.

```
EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;
```

Run a loop following the linked list to retrieve the rows.

```
sqlda_t *cur_sqlda;

for (cur_sqlda = sqlda1;
     cur_sqlda != NULL;
     cur_sqlda = cur_sqlda->desc_next)
{
    ...
}
```

Inside the loop, run another loop to retrieve each column data (`sqlvar_t` structure) of the row.

```
for (i = 0; i < cur_sqlda->sqld; i++)
{
    sqlvar_t v = cur_sqlda->sqlvar[i];
    char *sqldata = v.sqldata;
    short sqllen  = v.sqllen;
    ...
}
```

To get a column value, check the `sqltype` value, a member of the `sqlvar_t` structure. Then, switch to an appropriate way, depending on the column type, to copy data from the `sqlvar` field to a host variable.

```
char var_buf[1024];

switch (v.sqltype)
{
    case ECPGt_char:
        memset(&var_buf, 0, sizeof(var_buf));
        memcpy(&var_buf, sqldata, (sizeof(var_buf) <= sqllen ? sizeof(var_buf) - 1 : sql
        break;

    case ECPGt_int: /* integer */
        memcpy(&intval, sqldata, sqllen);
        snprintf(var_buf, sizeof(var_buf), "%d", intval);
        break;

    ...
```

```
}
```

33.7.2.3. Passing Query Parameters Using an SQLDA

The general steps to use an SQLDA to pass input parameters to a prepared query are:

1. Create a prepared query (prepared statement)
2. Declare a sqlda_t structure as an input SQLDA.
3. Allocate memory area (as sqlda_t structure) for the input SQLDA.
4. Set (copy) input values in the allocated memory.
5. Open a cursor with specifying the input SQLDA.

Here is an example.

First, create a prepared statement.

```
EXEC SQL BEGIN DECLARE SECTION;
char query[1024] = "SELECT d.oid, * FROM pg_database d, pg_stat_database s WHERE d.oid =
EXEC SQL END DECLARE SECTION;

EXEC SQL PREPARE stmt1 FROM :query;
```

Next, allocate memory for an SQLDA, and set the number of input parameters in `sqln`, a member variable of the `sqlda_t` structure. When two or more input parameters are required for the prepared query, the application has to allocate additional memory space which is calculated by (nr. of params - 1) * sizeof(sqlvar_t). The example shown here allocates memory space for two input parameters.

```
sqlda_t *sqlda2;

sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));

sqlda2->sqln = 2; /* number of input variables */
```

After memory allocation, store the parameter values into the `sqlvar[]` array. (This is same array used for retrieving column values when the SQLDA is receiving a result set.) In this example, the input parameters are `"postgres"`, having a string type, and `1`, having an integer type.

```
sqlda2->sqlvar[0].sqltype = ECPGt_char;
sqlda2->sqlvar[0].sqldata = "postgres";
sqlda2->sqlvar[0].sqllen  = 8;

int intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *) &intval;
sqlda2->sqlvar[1].sqllen  = sizeof(intval);
```

By opening a cursor and specifying the SQLDA that was set up beforehand, the input parameters are passed to the prepared statement.

```
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;
```

Finally, after using input SQLDAs, the allocated memory space must be freed explicitly, unlike SQLDAs used for receiving query results.

```
free(sqlda2);
```

33.7.2.4. A Sample Application Using SQLDA

Here is an example program, which describes how to fetch access statistics of the databases, specified by the input parameters, from the system catalogs.

This application joins two system tables, pg_database and pg_stat_database on the database OID, and also fetches and shows the database statistics which are retrieved by two input parameters (a database `postgres`, and OID `1`).

First, declare an SQLDA for input and an SQLDA for output.

```
EXEC SQL include sqlda.h;

sqlda_t *sqlda1; /* an output descriptor */
sqlda_t *sqlda2; /* an input descriptor  */
```

Next, connect to the database, prepare a statement, and declare a cursor for the prepared statement.

```
int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d, pg_stat_database s WHERE d.oi
    EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;

    EXEC SQL PREPARE stmt1 FROM :query;
    EXEC SQL DECLARE cur1 CURSOR FOR stmt1;
```

Next, put some values in the input SQLDA for the input parameters. Allocate memory for the input SQLDA, and set the number of input parameters to `sqln`. Store type, value, and value length into `sqltype`, `sqldata`, and `sqllen` in the `sqlvar` structure.

```
    /* Create SQLDA structure for input parameters. */
    sqlda2 = (sqlda_t *) malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
    memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
    sqlda2->sqln = 2; /* number of input variables */

    sqlda2->sqlvar[0].sqltype = ECPGt_char;
    sqlda2->sqlvar[0].sqldata = "postgres";
```

```
sqlda2->sqlvar[0].sqllen  = 8;

intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *)&intval;
sqlda2->sqlvar[1].sqllen  = sizeof(intval);
```

After setting up the input SQLDA, open a cursor with the input SQLDA.

```
/* Open a cursor with input parameters. */
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;
```

Fetch rows into the output SQLDA from the opened cursor. (Generally, you have to call `FETCH` repeatedly in the loop, to fetch all rows in the result set.)

```
while (1)
{
    sqlda_t *cur_sqlda;

    /* Assign descriptor to the cursor  */
    EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;
```

Next, retrieve the fetched records from the SQLDA, by following the linked list of the `sqlda_t` structure.

```
for (cur_sqlda = sqlda1 ;
     cur_sqlda != NULL ;
     cur_sqlda = cur_sqlda->desc_next)
{
    ...
```

Read each columns in the first record. The number of columns is stored in `sqld`, the actual data of the first column is stored in `sqlvar[0]`, both members of the `sqlda_t` structure.

```
    /* Print every column in a row. */
    for (i = 0; i < sqlda1->sqld; i++)
    {
        sqlvar_t v = sqlda1->sqlvar[i];
        char *sqldata = v.sqldata;
        short sqllen  = v.sqllen;

        strncpy(name_buf, v.sqlname.data, v.sqlname.length);
        name_buf[v.sqlname.length] = '\0';
```

Now, the column data is stored in the variable `v`. Copy every datum into host variables, looking at `v.sqltype` for the type of the column.

```
        switch (v.sqltype) {
            int intval;
            double doubleval;
```

```
                unsigned long long int longlongval;

                case ECPGt_char:
                    memset(&var_buf, 0, sizeof(var_buf));
                    memcpy(&var_buf, sqldata, (sizeof(var_buf) <= sqllen ? sizeof(var_bu
                    break;

                case ECPGt_int: /* integer */
                    memcpy(&intval, sqldata, sqllen);
                    snprintf(var_buf, sizeof(var_buf), "%d", intval);
                    break;

                ...

                default:
                    ...
            }

            printf("%s = %s (type: %d)\n", name_buf, var_buf, v.sqltype);
        }
```

Close the cursor after processing all of records, and disconnect from the database.

```
    EXEC SQL CLOSE cur1;
    EXEC SQL COMMIT;

    EXEC SQL DISCONNECT ALL;
```

The whole program is shown in Example 33-1.

Example 33-1. Example SQLDA Program

```
#include <stdlib.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>
#include <unistd.h>

EXEC SQL include sqlda.h;

sqlda_t *sqlda1; /* descriptor for output */
sqlda_t *sqlda2; /* descriptor for input */

EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    EXEC SQL BEGIN DECLARE SECTION;
    char query[1024] = "SELECT d.oid,* FROM pg_database d, pg_stat_database s WHERE d.oi

    int intval;
    unsigned long long int longlongval;
```

```
EXEC SQL END DECLARE SECTION;

EXEC SQL CONNECT TO uptimedb AS con1 USER uptime;

EXEC SQL PREPARE stmt1 FROM :query;
EXEC SQL DECLARE cur1 CURSOR FOR stmt1;

/* Create a SQLDA structure for an input parameter */
sqlda2 = (sqlda_t *)malloc(sizeof(sqlda_t) + sizeof(sqlvar_t));
memset(sqlda2, 0, sizeof(sqlda_t) + sizeof(sqlvar_t));
sqlda2->sqln = 2; /* a number of input variables */

sqlda2->sqlvar[0].sqltype = ECPGt_char;
sqlda2->sqlvar[0].sqldata = "postgres";
sqlda2->sqlvar[0].sqllen  = 8;

intval = 1;
sqlda2->sqlvar[1].sqltype = ECPGt_int;
sqlda2->sqlvar[1].sqldata = (char *) &intval;
sqlda2->sqlvar[1].sqllen  = sizeof(intval);

/* Open a cursor with input parameters. */
EXEC SQL OPEN cur1 USING DESCRIPTOR sqlda2;

while (1)
{
    sqlda_t *cur_sqlda;

    /* Assign descriptor to the cursor  */
    EXEC SQL FETCH NEXT FROM cur1 INTO DESCRIPTOR sqlda1;

    for (cur_sqlda = sqlda1 ;
         cur_sqlda != NULL ;
         cur_sqlda = cur_sqlda->desc_next)
    {
        int i;
        char name_buf[1024];
        char var_buf[1024];

        /* Print every column in a row. */
        for (i=0 ; i<cur_sqlda->sqld ; i++)
        {
            sqlvar_t v = cur_sqlda->sqlvar[i];
            char *sqldata = v.sqldata;
            short sqllen  = v.sqllen;

            strncpy(name_buf, v.sqlname.data, v.sqlname.length);
            name_buf[v.sqlname.length] = '\0';

            switch (v.sqltype)
            {
                case ECPGt_char:
                    memset(&var_buf, 0, sizeof(var_buf));
                    memcpy(&var_buf, sqldata, (sizeof(var_buf)<=sqllen ? sizeof(var_
                    break;

                case ECPGt_int: /* integer */
```

```
                        memcpy(&intval, sqldata, sqllen);
                        snprintf(var_buf, sizeof(var_buf), "%d", intval);
                        break;

                    case ECPGt_long_long: /* bigint */
                        memcpy(&longlongval, sqldata, sqllen);
                        snprintf(var_buf, sizeof(var_buf), "%lld", longlongval);
                        break;

                    default:
                    {
                        int i;
                        memset(var_buf, 0, sizeof(var_buf));
                        for (i = 0; i < sqllen; i++)
                        {
                            char tmpbuf[16];
                            snprintf(tmpbuf, sizeof(tmpbuf), "%02x ", (unsigned char) sq
                            strncat(var_buf, tmpbuf, sizeof(var_buf));
                        }
                    }
                        break;
                }

                printf("%s = %s (type: %d)\n", name_buf, var_buf, v.sqltype);
            }

            printf("\n");
        }
    }

    EXEC SQL CLOSE cur1;
    EXEC SQL COMMIT;

    EXEC SQL DISCONNECT ALL;

    return 0;
}
```

The output of this example should look something like the following (some numbers will vary).

```
oid = 1 (type: 1)
datname = template1 (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = t (type: 1)
datallowconn = t (type: 1)
datconnlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig =  (type: 1)
datacl = {=c/uptime,uptime=CTc/uptime} (type: 1)
datid = 1 (type: 1)
datname = template1 (type: 1)
numbackends = 0 (type: 5)
xact_commit = 113606 (type: 9)
xact_rollback = 0 (type: 9)
blks_read = 130 (type: 9)
```

```
blks_hit = 7341714 (type: 9)
tup_returned = 38262679 (type: 9)
tup_fetched = 1836281 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)

oid = 11511 (type: 1)
datname = postgres (type: 1)
datdba = 10 (type: 1)
encoding = 0 (type: 5)
datistemplate = f (type: 1)
datallowconn = t (type: 1)
datconnlimit = -1 (type: 5)
datlastsysoid = 11510 (type: 1)
datfrozenxid = 379 (type: 1)
dattablespace = 1663 (type: 1)
datconfig =  (type: 1)
datacl =  (type: 1)
datid = 11511 (type: 1)
datname = postgres (type: 1)
numbackends = 0 (type: 5)
xact_commit = 221069 (type: 9)
xact_rollback = 18 (type: 9)
blks_read = 1176 (type: 9)
blks_hit = 13943750 (type: 9)
tup_returned = 77410091 (type: 9)
tup_fetched = 3253694 (type: 9)
tup_inserted = 0 (type: 9)
tup_updated = 0 (type: 9)
tup_deleted = 0 (type: 9)
```

33.8. Error Handling

This section describes how you can handle exceptional conditions and warnings in an embedded SQL program. There are two nonexclusive facilities for this.

- Callbacks can be configured to handle warning and error conditions using the `WHENEVER` command.
- Detailed information about the error or warning can be obtained from the `sqlca` variable.

33.8.1. Setting Callbacks

One simple method to catch errors and warnings is to set a specific action to be executed whenever a particular condition occurs. In general:

```
EXEC SQL WHENEVER condition action;
```

condition can be one of the following:

SQLERROR

The specified action is called whenever an error occurs during the execution of an SQL statement.

SQLWARNING

The specified action is called whenever a warning occurs during the execution of an SQL statement.

NOT FOUND

The specified action is called whenever an SQL statement retrieves or affects zero rows. (This condition is not an error, but you might be interested in handling it specially.)

action can be one of the following:

CONTINUE

This effectively means that the condition is ignored. This is the default.

GOTO *label*
GO TO *label*

Jump to the specified label (using a C `goto` statement).

SQLPRINT

Print a message to standard error. This is useful for simple programs or during prototyping. The details of the message cannot be configured.

STOP

Call `exit(1)`, which will terminate the program.

DO BREAK

Execute the C statement `break`. This should only be used in loops or `switch` statements.

CALL *name* (*args*)
DO *name* (*args*)

Call the specified C functions with the specified arguments.

The SQL standard only provides for the actions `CONTINUE` and `GOTO` (and `GO TO`).

Here is an example that you might want to use in a simple program. It prints a simple message when a warning occurs and aborts the program when an error happens:

```
EXEC SQL WHENEVER SQLWARNING SQLPRINT;
EXEC SQL WHENEVER SQLERROR STOP;
```

The statement `EXEC SQL WHENEVER` is a directive of the SQL preprocessor, not a C statement. The error or warning actions that it sets apply to all embedded SQL statements that appear below the point where the handler is set, unless a different action was set for the same condition between the first `EXEC SQL WHENEVER` and the SQL statement causing the condition, regardless of the flow of control in the C program. So neither of the two following C program excerpts will have the desired effect:

```
/*
 * WRONG
 */
```

```
int main(int argc, char *argv[])
{
    ...
    if (verbose) {
        EXEC SQL WHENEVER SQLWARNING SQLPRINT;
    }
    ...
    EXEC SQL SELECT ...;
    ...
}

/*
 * WRONG
 */
int main(int argc, char *argv[])
{
    ...
    set_error_handler();
    ...
    EXEC SQL SELECT ...;
    ...
}

static void set_error_handler(void)
{
    EXEC SQL WHENEVER SQLERROR STOP;
}
```

33.8.2. sqlca

For more powerful error handling, the embedded SQL interface provides a global variable with the name `sqlca` (SQL communication area) that has the following structure:

```
struct
{
    char sqlcaid[8];
    long sqlabc;
    long sqlcode;
    struct
    {
        int sqlerrml;
        char sqlerrmc[SQLERRMC_LEN];
    } sqlerrm;
    char sqlerrp[8];
    long sqlerrd[6];
    char sqlwarn[8];
    char sqlstate[5];
} sqlca;
```

(In a multithreaded program, every thread automatically gets its own copy of `sqlca`. This works similarly to the handling of the standard C global variable `errno`.)

`sqlca` covers both warnings and errors. If multiple warnings or errors occur during the execution of a statement, then `sqlca` will only contain information about the last one.

If no error occurred in the last SQL statement, `sqlca.sqlcode` will be 0 and `sqlca.sqlstate` will be `"00000"`. If a warning or error occurred, then `sqlca.sqlcode` will be negative and `sqlca.sqlstate` will be different from `"00000"`. A positive `sqlca.sqlcode` indicates a harmless condition, such as that the last query returned zero rows. `sqlcode` and `sqlstate` are two different error code schemes; details appear below.

If the last SQL statement was successful, then `sqlca.sqlerrd[1]` contains the OID of the processed row, if applicable, and `sqlca.sqlerrd[2]` contains the number of processed or returned rows, if applicable to the command.

In case of an error or warning, `sqlca.sqlerrm.sqlerrmc` will contain a string that describes the error. The field `sqlca.sqlerrm.sqlerrml` contains the length of the error message that is stored in `sqlca.sqlerrm.sqlerrmc` (the result of `strlen()`, not really interesting for a C programmer). Note that some messages are too long to fit in the fixed-size `sqlerrmc` array; they will be truncated.

In case of a warning, `sqlca.sqlwarn[2]` is set to `W`. (In all other cases, it is set to something different from `W`.) If `sqlca.sqlwarn[1]` is set to `W`, then a value was truncated when it was stored in a host variable. `sqlca.sqlwarn[0]` is set to `W` if any of the other elements are set to indicate a warning.

The fields `sqlcaid`, `sqlcabc`, `sqlerrp`, and the remaining elements of `sqlerrd` and `sqlwarn` currently contain no useful information.

The structure `sqlca` is not defined in the SQL standard, but is implemented in several other SQL database systems. The definitions are similar at the core, but if you want to write portable applications, then you should investigate the different implementations carefully.

Here is one example that combines the use of `WHENEVER` and `sqlca`, printing out the contents of `sqlca` when an error occurs. This is perhaps useful for debugging or prototyping applications, before installing a more "user-friendly" error handler.

```
EXEC SQL WHENEVER SQLERROR CALL print_sqlca();

void
print_sqlca()
{
    fprintf(stderr, "==== sqlca ====\n");
    fprintf(stderr, "sqlcode: %ld\n", sqlca.sqlcode);
    fprintf(stderr, "sqlerrm.sqlerrml: %d\n", sqlca.sqlerrm.sqlerrml);
    fprintf(stderr, "sqlerrm.sqlerrmc: %s\n", sqlca.sqlerrm.sqlerrmc);
    fprintf(stderr, "sqlerrd: %ld %ld %ld %ld %ld %ld\n", sqlca.sqlerrd[0],sqlca.sqlerrd
                                                          sqlca.sqlerrd[3],sqlca.sqlerrd
    fprintf(stderr, "sqlwarn: %d %d %d %d %d %d %d %d\n", sqlca.sqlwarn[0], sqlca.sqlwar
                                                          sqlca.sqlwarn[3], sqlca.sqlwar
                                                          sqlca.sqlwarn[6], sqlca.sqlwar
    fprintf(stderr, "sqlstate: %5s\n", sqlca.sqlstate);
    fprintf(stderr, "===============\n");
}
```

The result could look as follows (here an error due to a misspelled table name):

```
==== sqlca ====
sqlcode: -400
sqlerrm.sqlerrml: 49
sqlerrm.sqlerrmc: relation "pg_databasep" does not exist on line 38
sqlerrd: 0 0 0 0 0 0
sqlwarn: 0 0 0 0 0 0 0 0
sqlstate: 42P01
===============
```

33.8.3. SQLSTATE vs. SQLCODE

The fields sqlca.sqlstate and sqlca.sqlcode are two different schemes that provide error codes. Both are derived from the SQL standard, but SQLCODE has been marked deprecated in the SQL-92 edition of the standard and has been dropped in later editions. Therefore, new applications are strongly encouraged to use SQLSTATE.

SQLSTATE is a five-character array. The five characters contain digits or upper-case letters that represent codes of various error and warning conditions. SQLSTATE has a hierarchical scheme: the first two characters indicate the general class of the condition, the last three characters indicate a subclass of the general condition. A successful state is indicated by the code 00000. The SQLSTATE codes are for the most part defined in the SQL standard. The PostgreSQL server natively supports SQLSTATE error codes; therefore a high degree of consistency can be achieved by using this error code scheme throughout all applications. For further information see Appendix A.

SQLCODE, the deprecated error code scheme, is a simple integer. A value of 0 indicates success, a positive value indicates success with additional information, a negative value indicates an error. The SQL standard only defines the positive value +100, which indicates that the last command returned or affected zero rows, and no specific negative values. Therefore, this scheme can only achieve poor portability and does not have a hierarchical code assignment. Historically, the embedded SQL processor for PostgreSQL has assigned some specific SQLCODE values for its use, which are listed below with their numeric value and their symbolic name. Remember that these are not portable to other SQL implementations. To simplify the porting of applications to the SQLSTATE scheme, the corresponding SQLSTATE is also listed. There is, however, no one-to-one or one-to-many mapping between the two schemes (indeed it is many-to-many), so you should consult the global SQLSTATE listing in Appendix A in each case.

These are the assigned SQLCODE values:

0 (ECPG_NO_ERROR)

Indicates no error. (SQLSTATE 00000)

100 (ECPG_NOT_FOUND)

This is a harmless condition indicating that the last command retrieved or processed zero rows, or that you are at the end of the cursor. (SQLSTATE 02000)

When processing a cursor in a loop, you could use this code as a way to detect when to abort the loop, like this:

```
while (1)
{
    EXEC SQL FETCH ... ;
    if (sqlca.sqlcode == ECPG_NOT_FOUND)
        break;
}
```

But WHENEVER NOT FOUND DO BREAK effectively does this internally, so there is usually no advantage in writing this out explicitly.

-12 (ECPG_OUT_OF_MEMORY)

Indicates that your virtual memory is exhausted. The numeric value is defined as -ENOMEM. (SQLSTATE YE001)

-200 (`ECPG_UNSUPPORTED`)

Indicates the preprocessor has generated something that the library does not know about. Perhaps you are running incompatible versions of the preprocessor and the library. (SQLSTATE YE002)

-201 (`ECPG_TOO_MANY_ARGUMENTS`)

This means that the command specified more host variables than the command expected. (SQLSTATE 07001 or 07002)

-202 (`ECPG_TOO_FEW_ARGUMENTS`)

This means that the command specified fewer host variables than the command expected. (SQLSTATE 07001 or 07002)

-203 (`ECPG_TOO_MANY_MATCHES`)

This means a query has returned multiple rows but the statement was only prepared to store one result row (for example, because the specified variables are not arrays). (SQLSTATE 21000)

-204 (`ECPG_INT_FORMAT`)

The host variable is of type `int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `int`. The library uses `strtol()` for this conversion. (SQLSTATE 42804)

-205 (`ECPG_UINT_FORMAT`)

The host variable is of type `unsigned int` and the datum in the database is of a different type and contains a value that cannot be interpreted as an `unsigned int`. The library uses `strtoul()` for this conversion. (SQLSTATE 42804)

-206 (`ECPG_FLOAT_FORMAT`)

The host variable is of type `float` and the datum in the database is of another type and contains a value that cannot be interpreted as a `float`. The library uses `strtod()` for this conversion. (SQLSTATE 42804)

-207 (`ECPG_NUMERIC_FORMAT`)

The host variable is of type `numeric` and the datum in the database is of another type and contains a value that cannot be interpreted as a `numeric` value. (SQLSTATE 42804)

-208 (`ECPG_INTERVAL_FORMAT`)

The host variable is of type `interval` and the datum in the database is of another type and contains a value that cannot be interpreted as an `interval` value. (SQLSTATE 42804)

-209 (`ECPG_DATE_FORMAT`)

The host variable is of type `date` and the datum in the database is of another type and contains a value that cannot be interpreted as a `date` value. (SQLSTATE 42804)

-210 (`ECPG_TIMESTAMP_FORMAT`)

The host variable is of type `timestamp` and the datum in the database is of another type and contains a value that cannot be interpreted as a `timestamp` value. (SQLSTATE 42804)

-211 (`ECPG_CONVERT_BOOL`)

This means the host variable is of type `bool` and the datum in the database is neither `'t'` nor `'f'`. (SQLSTATE 42804)

-212 (`ECPG_EMPTY`)

The statement sent to the PostgreSQL server was empty. (This cannot normally happen in an embedded SQL program, so it might point to an internal error.) (SQLSTATE YE002)

-213 (ECPG_MISSING_INDICATOR)

A null value was returned and no null indicator variable was supplied. (SQLSTATE 22002)

-214 (ECPG_NO_ARRAY)

An ordinary variable was used in a place that requires an array. (SQLSTATE 42804)

-215 (ECPG_DATA_NOT_ARRAY)

The database returned an ordinary variable in a place that requires array value. (SQLSTATE 42804)

-220 (ECPG_NO_CONN)

The program tried to access a connection that does not exist. (SQLSTATE 08003)

-221 (ECPG_NOT_CONN)

The program tried to access a connection that does exist but is not open. (This is an internal error.) (SQLSTATE YE002)

-230 (ECPG_INVALID_STMT)

The statement you are trying to use has not been prepared. (SQLSTATE 26000)

-239 (ECPG_INFORMIX_DUPLICATE_KEY)

Duplicate key error, violation of unique constraint (Informix compatibility mode). (SQLSTATE 23505)

-240 (ECPG_UNKNOWN_DESCRIPTOR)

The descriptor specified was not found. The statement you are trying to use has not been prepared. (SQLSTATE 33000)

-241 (ECPG_INVALID_DESCRIPTOR_INDEX)

The descriptor index specified was out of range. (SQLSTATE 07009)

-242 (ECPG_UNKNOWN_DESCRIPTOR_ITEM)

An invalid descriptor item was requested. (This is an internal error.) (SQLSTATE YE002)

-243 (ECPG_VAR_NOT_NUMERIC)

During the execution of a dynamic statement, the database returned a numeric value and the host variable was not numeric. (SQLSTATE 07006)

-244 (ECPG_VAR_NOT_CHAR)

During the execution of a dynamic statement, the database returned a non-numeric value and the host variable was numeric. (SQLSTATE 07006)

-284 (ECPG_INFORMIX_SUBSELECT_NOT_ONE)

A result of the subquery is not single row (Informix compatibility mode). (SQLSTATE 21000)

-400 (ECPG_PGSQL)

Some error caused by the PostgreSQL server. The message contains the error message from the PostgreSQL server.

-401 (ECPG_TRANS)

The PostgreSQL server signaled that we cannot start, commit, or rollback the transaction. (SQLSTATE 08007)

-402 (ECPG_CONNECT)

The connection attempt to the database did not succeed. (SQLSTATE 08001)

-403 (ECPG_DUPLICATE_KEY)

Duplicate key error, violation of unique constraint. (SQLSTATE 23505)

-404 (ECPG_SUBSELECT_NOT_ONE)

A result for the subquery is not single row. (SQLSTATE 21000)

-602 (ECPG_WARNING_UNKNOWN_PORTAL)

An invalid cursor name was specified. (SQLSTATE 34000)

-603 (ECPG_WARNING_IN_TRANSACTION)

Transaction is in progress. (SQLSTATE 25001)

-604 (ECPG_WARNING_NO_TRANSACTION)

There is no active (in-progress) transaction. (SQLSTATE 25P01)

-605 (ECPG_WARNING_PORTAL_EXISTS)

An existing cursor name was specified. (SQLSTATE 42P03)

33.9. Preprocessor Directives

Several preprocessor directives are available that modify how the ecpg preprocessor parses and processes a file.

33.9.1. Including Files

To include an external file into your embedded SQL program, use:

```
EXEC SQL INCLUDE filename;
EXEC SQL INCLUDE <filename>;
EXEC SQL INCLUDE "filename";
```

The embedded SQL preprocessor will look for a file named *filename*.h, preprocess it, and include it in the resulting C output. Thus, embedded SQL statements in the included file are handled correctly.

The ecpg preprocessor will search a file at several directories in following order:

- current directory
- /usr/local/include
- PostgreSQL include directory, defined at build time (e.g., /usr/local/pgsql/include)
- /usr/include

But when EXEC SQL INCLUDE "*filename*" is used, only the current directory is searched.

In each directory, the preprocessor will first look for the file name as given, and if not found will append .h to the file name and try again (unless the specified file name already has that suffix).

Note that EXEC SQL INCLUDE is *not* the same as:

```
#include <filename.h>
```

because this file would not be subject to SQL command preprocessing. Naturally, you can continue to use the C `#include` directive to include other header files.

> **Note:** The include file name is case-sensitive, even though the rest of the `EXEC SQL INCLUDE` command follows the normal SQL case-sensitivity rules.

33.9.2. The define and undef Directives

Similar to the directive `#define` that is known from C, embedded SQL has a similar concept:

```
EXEC SQL DEFINE name;
EXEC SQL DEFINE name value;
```

So you can define a name:

```
EXEC SQL DEFINE HAVE_FEATURE;
```

And you can also define constants:

```
EXEC SQL DEFINE MYNUMBER 12;
EXEC SQL DEFINE MYSTRING 'abc';
```

Use `undef` to remove a previous definition:

```
EXEC SQL UNDEF MYNUMBER;
```

Of course you can continue to use the C versions `#define` and `#undef` in your embedded SQL program. The difference is where your defined values get evaluated. If you use `EXEC SQL DEFINE` then the `ecpg` preprocessor evaluates the defines and substitutes the values. For example if you write:

```
EXEC SQL DEFINE MYNUMBER 12;
...
EXEC SQL UPDATE Tbl SET col = MYNUMBER;
```

then `ecpg` will already do the substitution and your C compiler will never see any name or identifier `MYNUMBER`. Note that you cannot use `#define` for a constant that you are going to use in an embedded SQL query because in this case the embedded SQL precompiler is not able to see this declaration.

33.9.3. ifdef, ifndef, else, elif, and endif Directives

You can use the following directives to compile code sections conditionally:

`EXEC SQL ifdef name;`

Checks a *name* and processes subsequent lines if *name* has been created with `EXEC SQL define name`.

`EXEC SQL ifndef name;`

Checks a *name* and processes subsequent lines if *name* has *not* been created with `EXEC SQL define name`.

`EXEC SQL else;`

Starts processing an alternative section to a section introduced by either `EXEC SQL ifdef` *`name`* or `EXEC SQL ifndef` *`name`*.

`EXEC SQL elif` *`name`*`;`

Checks *`name`* and starts an alternative section if *`name`* has been created with `EXEC SQL define` *`name`*.

`EXEC SQL endif;`

Ends an alternative section.

Example:

```
EXEC SQL ifndef TZVAR;
EXEC SQL SET TIMEZONE TO 'GMT';
EXEC SQL elif TZNAME;
EXEC SQL SET TIMEZONE TO TZNAME;
EXEC SQL else;
EXEC SQL SET TIMEZONE TO TZVAR;
EXEC SQL endif;
```

33.10. Processing Embedded SQL Programs

Now that you have an idea how to form embedded SQL C programs, you probably want to know how to compile them. Before compiling you run the file through the embedded SQL C preprocessor, which converts the SQL statements you used to special function calls. After compiling, you must link with a special library that contains the needed functions. These functions fetch information from the arguments, perform the SQL command using the libpq interface, and put the result in the arguments specified for output.

The preprocessor program is called `ecpg` and is included in a normal PostgreSQL installation. Embedded SQL programs are typically named with an extension `.pgc`. If you have a program file called `prog1.pgc`, you can preprocess it by simply calling:

```
ecpg prog1.pgc
```

This will create a file called `prog1.c`. If your input files do not follow the suggested naming pattern, you can specify the output file explicitly using the `-o` option.

The preprocessed file can be compiled normally, for example:

```
cc -c prog1.c
```

The generated C source files include header files from the PostgreSQL installation, so if you installed PostgreSQL in a location that is not searched by default, you have to add an option such as `-I/usr/local/pgsql/include` to the compilation command line.

To link an embedded SQL program, you need to include the `libecpg` library, like so:

```
cc -o myprog prog1.o prog2.o ... -lecpg
```

Again, you might have to add an option like `-L/usr/local/pgsql/lib` to that command line.

You can use `pg_config` or `pkg-config` with package name `libecpg` to get the paths for your installation.

If you manage the build process of a larger project using make, it might be convenient to include the following implicit rule to your makefiles:

```
ECPG = ecpg

%.c: %.pgc
        $(ECPG) $<
```

The complete syntax of the `ecpg` command is detailed in ecpg.

The ecpg library is thread-safe by default. However, you might need to use some threading command-line options to compile your client code.

33.11. Library Functions

The `libecpg` library primarily contains "hidden" functions that are used to implement the functionality expressed by the embedded SQL commands. But there are some functions that can usefully be called directly. Note that this makes your code unportable.

- `ECPGdebug(int` *`on`*`, FILE *`*`stream`*`)` turns on debug logging if called with the first argument non-zero. Debug logging is done on *`stream`*. The log contains all SQL statements with all the input variables inserted, and the results from the PostgreSQL server. This can be very useful when searching for errors in your SQL statements.

  Note: On Windows, if the ecpg libraries and an application are compiled with different flags, this function call will crash the application because the internal representation of the `FILE` pointers differ. Specifically, multithreaded/single-threaded, release/debug, and static/dynamic flags should be the same for the library and all applications using that library.

- `ECPGget_PGconn(const char *`*`connection_name`*`)` returns the library database connection handle identified by the given name. If *`connection_name`* is set to `NULL`, the current connection handle is returned. If no connection handle can be identified, the function returns `NULL`. The returned connection handle can be used to call any other functions from libpq, if necessary.

  Note: It is a bad idea to manipulate database connection handles made from ecpg directly with libpq routines.

- `ECPGtransactionStatus(const char *`*`connection_name`*`)` returns the current transaction status of the given connection identified by *`connection_name`*. See Section 31.2 and libpq's `PQtransactionStatus()` for details about the returned status codes.

- `ECPGstatus(int lineno, const char* connection_name)` returns true if you are connected to a database and false if not. *connection_name* can be `NULL` if a single connection is being used.

33.12. Large Objects

Large objects are not directly supported by ECPG, but ECPG application can manipulate large objects through the libpq large object functions, obtaining the necessary `PGconn` object by calling the `ECPGget_PGconn()` function. (However, use of the `ECPGget_PGconn()` function and touching `PGconn` objects directly should be done very carefully and ideally not mixed with other ECPG database access calls.)

For more details about the `ECPGget_PGconn()`, see Section 33.11. For information about the large object function interface, see Chapter 32.

Large object functions have to be called in a transaction block, so when autocommit is off, `BEGIN` commands have to be issued explicitly.

Example 33-2 shows an example program that illustrates how to create, write, and read a large object in an ECPG application.

Example 33-2. ECPG Program Accessing Large Objects

```
#include <stdio.h>
#include <stdlib.h>
#include <libpq-fe.h>
#include <libpq/libpq-fs.h>

EXEC SQL WHENEVER SQLERROR STOP;

int
main(void)
{
    PGconn     *conn;
    Oid         loid;
    int         fd;
    char        buf[256];
    int         buflen = 256;
    char        buf2[256];
    int         rc;

    memset(buf, 1, buflen);

    EXEC SQL CONNECT TO testdb AS con1;

    conn = ECPGget_PGconn("con1");
    printf("conn = %p\n", conn);

    /* create */
    loid = lo_create(conn, 0);
    if (loid &lt; 0)
        printf("lo_create() failed: %s", PQerrorMessage(conn));

    printf("loid = %d\n", loid);

    /* write test */
```

```
    fd = lo_open(conn, loid, INV_READ|INV_WRITE);
    if (fd &lt; 0)
        printf("lo_open() failed: %s", PQerrorMessage(conn));

    printf("fd = %d\n", fd);

    rc = lo_write(conn, fd, buf, buflen);
    if (rc &lt; 0)
        printf("lo_write() failed\n");

    rc = lo_close(conn, fd);
    if (rc &lt; 0)
        printf("lo_close() failed: %s", PQerrorMessage(conn));

    /* read test */
    fd = lo_open(conn, loid, INV_READ);
    if (fd &lt; 0)
        printf("lo_open() failed: %s", PQerrorMessage(conn));

    printf("fd = %d\n", fd);

    rc = lo_read(conn, fd, buf2, buflen);
    if (rc &lt; 0)
        printf("lo_read() failed\n");

    rc = lo_close(conn, fd);
    if (rc &lt; 0)
        printf("lo_close() failed: %s", PQerrorMessage(conn));

    /* check */
    rc = memcmp(buf, buf2, buflen);
    printf("memcmp() = %d\n", rc);

    /* cleanup */
    rc = lo_unlink(conn, loid);
    if (rc &lt; 0)
        printf("lo_unlink() failed: %s", PQerrorMessage(conn));

    EXEC SQL COMMIT;
    EXEC SQL DISCONNECT ALL;
    return 0;
}
```

33.13. C++ Applications

ECPG has some limited support for C++ applications. This section describes some caveats.

The `ecpg` preprocessor takes an input file written in C (or something like C) and embedded SQL commands, converts the embedded SQL commands into C language chunks, and finally generates a `.c` file. The header file declarations of the library functions used by the C language chunks that `ecpg` generates are wrapped in `extern "C" { ... }` blocks when used under C++, so they should work seamlessly in C++.

In general, however, the `ecpg` preprocessor only understands C; it does not handle the special syntax and reserved words of the C++ language. So, some embedded SQL code written in C++ application

code that uses complicated features specific to C++ might fail to be preprocessed correctly or might not work as expected.

A safe way to use the embedded SQL code in a C++ application is hiding the ECPG calls in a C module, which the C++ application code calls into to access the database, and linking that together with the rest of the C++ code. See Section 33.13.2 about that.

33.13.1. Scope for Host Variables

The `ecpg` preprocessor understands the scope of variables in C. In the C language, this is rather simple because the scopes of variables is based on their code blocks. In C++, however, the class member variables are referenced in a different code block from the declared position, so the `ecpg` preprocessor will not understand the scope of the class member variables.

For example, in the following case, the `ecpg` preprocessor cannot find any declaration for the variable `dbname` in the `test` method, so an error will occur.

```
class TestCpp
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

  public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    EXEC SQL CONNECT TO testdb1;
}

void Test::test()
{
    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

TestCpp::~TestCpp()
{
    EXEC SQL DISCONNECT ALL;
}
```

This code will result in an error like this:

```
ecpg test_cpp.pgc
test_cpp.pgc:28: ERROR: variable "dbname" is not declared
```

To avoid this scope issue, the `test` method could be modified to use a local variable as intermediate storage. But this approach is only a poor workaround, because it uglifies the code and reduces performance.

```
void TestCpp::test()
```

```
{
    EXEC SQL BEGIN DECLARE SECTION;
    char tmp[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :tmp;
    strlcpy(dbname, tmp, sizeof(tmp));

    printf("current_database = %s\n", dbname);
}
```

33.13.2. C++ Application Development with External C Module

If you understand these technical limitations of the `ecpg` preprocessor in C++, you might come to the conclusion that linking C objects and C++ objects at the link stage to enable C++ applications to use ECPG features could be better than writing some embedded SQL commands in C++ code directly. This section describes a way to separate some embedded SQL commands from C++ application code with a simple example. In this example, the application is implemented in C++, while C and ECPG is used to connect to the PostgreSQL server.

Three kinds of files have to be created: a C file (`*.pgc`), a header file, and a C++ file:

`test_mod.pgc`

A sub-routine module to execute SQL commands embedded in C. It is going to be converted into `test_mod.c` by the preprocessor.

```
#include "test_mod.h"
#include <stdio.h>

void
db_connect()
{
    EXEC SQL CONNECT TO testdb1;
}

void
db_test()
{
    EXEC SQL BEGIN DECLARE SECTION;
    char dbname[1024];
    EXEC SQL END DECLARE SECTION;

    EXEC SQL SELECT current_database() INTO :dbname;
    printf("current_database = %s\n", dbname);
}

void
db_disconnect()
{
    EXEC SQL DISCONNECT ALL;
}
```

`test_mod.h`

A header file with declarations of the functions in the C module (`test_mod.pgc`). It is included by `test_cpp.cpp`. This file has to have an `extern "C"` block around the declarations, because it will be linked from the C++ module.

```
#ifdef __cplusplus
extern "C" {
#endif

void db_connect();
void db_test();
void db_disconnect();

#ifdef __cplusplus
}
#endif
```

`test_cpp.cpp`

The main code for the application, including the `main` routine, and in this example a C++ class.

```
#include "test_mod.h"

class TestCpp
{
  public:
    TestCpp();
    void test();
    ~TestCpp();
};

TestCpp::TestCpp()
{
    db_connect();
}

void
TestCpp::test()
{
    db_test();
}

TestCpp::~TestCpp()
{
    db_disconnect();
}

int
main(void)
{
    TestCpp *t = new TestCpp();

    t->test();
    return 0;
}
```

To build the application, proceed as follows. Convert `test_mod.pgc` into `test_mod.c` by running `ecpg`, and generate `test_mod.o` by compiling `test_mod.c` with the C compiler:

```
ecpg -o test_mod.c test_mod.pgc
cc -c test_mod.c -o test_mod.o
```

Next, generate `test_cpp.o` by compiling `test_cpp.cpp` with the C++ compiler:.

```
c++ -c test_cpp.cpp -o test_cpp.o
```

Finally, link these object files, `test_cpp.o` and `test_mod.o`, into one executable, using the C++ compiler driver:

```
c++ test_cpp.o test_mod.o -lecpg -o test_cpp
```

33.14. Embedded SQL Commands

This section describes all SQL commands that are specific to embedded SQL. Also refer to the SQL commands listed in Reference I, *SQL Commands*, which can also be used in embedded SQL, unless stated otherwise.

ALLOCATE DESCRIPTOR

Name

`ALLOCATE DESCRIPTOR` — allocate an SQL descriptor area

Synopsis

```
ALLOCATE DESCRIPTOR name
```

Description

`ALLOCATE DESCRIPTOR` allocates a new named SQL descriptor area, which can be used to exchange data between the PostgreSQL server and the host program.

Descriptor areas should be freed after use using the `DEALLOCATE DESCRIPTOR` command.

Parameters

name

A name of SQL descriptor, case sensitive. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;
```

Compatibility

`ALLOCATE DESCRIPTOR` is specified in the SQL standard.

See Also

DEALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR

CONNECT

Name

CONNECT — establish a database connection

Synopsis

```
CONNECT TO connection_target [ AS connection_name ] [ USER connection_user_name ]
CONNECT TO DEFAULT
CONNECT connection_user_name
DATABASE connection_target
```

Description

The CONNECT command establishes a connection between the client and the PostgreSQL server.

Parameters

connection_target

connection_target specifies the target server of the connection on one of several forms.

[*database_name*] [@*host*] [:*port*]

Connect over TCP/IP

unix:postgresql://*host* [:*port*] / [*database_name*] [?*connection_option*]

Connect over Unix-domain sockets

tcp:postgresql://*host* [:*port*] / [*database_name*] [?*connection_option*]

Connect over TCP/IP

SQL string constant

containing a value in one of the above forms

host variable

host variable of type char[] or VARCHAR[] containing a value in one of the above forms

connection_object

An optional identifier for the connection, so that it can be referred to in other commands. This can be an SQL identifier or a host variable.

connection_user

The user name for the database connection.

This parameter can also specify user name and password, using one the forms *user_name*/*password*, *user_name* IDENTIFIED BY *password*, or *user_name* USING *password*.

User name and password can be SQL identifiers, string constants, or host variables.

`DEFAULT`

Use all default connection parameters, as defined by libpq.

Examples

Here a several variants for specifying connection parameters:

```
EXEC SQL CONNECT TO "connectdb" AS main;
EXEC SQL CONNECT TO "connectdb" AS second;
EXEC SQL CONNECT TO "unix:postgresql://200.46.204.71/connectdb" AS main USER connectuser
EXEC SQL CONNECT TO "unix:postgresql://localhost/connectdb" AS main USER connectuser;
EXEC SQL CONNECT TO 'connectdb' AS main;
EXEC SQL CONNECT TO 'unix:postgresql://localhost/connectdb' AS main USER :user;
EXEC SQL CONNECT TO :db AS :id;
EXEC SQL CONNECT TO :db USER connectuser USING :pw;
EXEC SQL CONNECT TO @localhost AS main USER connectdb;
EXEC SQL CONNECT TO REGRESSDB1 as main;
EXEC SQL CONNECT TO AS main USER connectdb;
EXEC SQL CONNECT TO connectdb AS :id;
EXEC SQL CONNECT TO connectdb AS main USER connectuser/connectdb;
EXEC SQL CONNECT TO connectdb AS main;
EXEC SQL CONNECT TO connectdb@localhost AS main;
EXEC SQL CONNECT TO tcp:postgresql://localhost/ USER connectdb;
EXEC SQL CONNECT TO tcp:postgresql://localhost/connectdb USER connectuser IDENTIFIED BY
EXEC SQL CONNECT TO tcp:postgresql://localhost:20/connectdb USER connectuser IDENTIFIED
EXEC SQL CONNECT TO unix:postgresql://localhost/ AS main USER connectdb;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb AS main USER connectuser;
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER connectuser IDENTIFIED BY
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb USER connectuser USING "connec
EXEC SQL CONNECT TO unix:postgresql://localhost/connectdb?connect_timeout=14 USER connec
```

Here is an example program that illustrates the use of host variables to specify connection parameters:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    char *dbname     = "testdb";    /* database name */
    char *user       = "testuser";  /* connection user name */
    char *connection = "tcp:postgresql://localhost:5432/testdb";
                                    /* connection string */
    char ver[256];                  /* buffer to store the version string */
EXEC SQL END DECLARE SECTION;

    ECPGdebug(1, stderr);

    EXEC SQL CONNECT TO :dbname USER :user;
    EXEC SQL SELECT version() INTO :ver;
    EXEC SQL DISCONNECT;

    printf("version: %s\n", ver);
```

```
    EXEC SQL CONNECT TO :connection USER :user;
    EXEC SQL SELECT version() INTO :ver;
    EXEC SQL DISCONNECT;

    printf("version: %s\n", ver);

    return 0;
}
```

Compatibility

`CONNECT` is specified in the SQL standard, but the format of the connection parameters is implementation-specific.

See Also

DISCONNECT, SET CONNECTION

DEALLOCATE DESCRIPTOR

Name

`DEALLOCATE DESCRIPTOR` — deallocate an SQL descriptor area

Synopsis

```
DEALLOCATE DESCRIPTOR name
```

Description

`DEALLOCATE DESCRIPTOR` deallocates a named SQL descriptor area.

Parameters

name

The name of the descriptor which is going to be deallocated. It is case sensitive. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

Compatibility

`DEALLOCATE DESCRIPTOR` is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR, SET DESCRIPTOR

DECLARE

Name

DECLARE — define a cursor

Synopsis

```
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ] CURSOR [ { WITH | WITHOU
DECLARE cursor_name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ] CURSOR [ { WITH | WITHOU
```

Description

DECLARE declares a cursor for iterating over the result set of a prepared statement. This command has slightly different semantics from the direct SQL command DECLARE: Whereas the latter executes a query and prepares the result set for retrieval, this embedded SQL command merely declares a name as a "loop variable" for iterating over the result set of a query; the actual execution happens when the cursor is opened with the OPEN command.

Parameters

cursor_name

A cursor name, case sensitive. This can be an SQL identifier or a host variable.

prepared_name

The name of a prepared query, either as an SQL identifier or a host variable.

query

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

For the meaning of the cursor options, see DECLARE.

Examples

Examples declaring a cursor for a query:

```
EXEC SQL DECLARE C CURSOR FOR SELECT * FROM My_Table;
EXEC SQL DECLARE C CURSOR FOR SELECT Item1 FROM T;
EXEC SQL DECLARE cur1 CURSOR FOR SELECT version();
```

An example declaring a cursor for a prepared statement:

```
EXEC SQL PREPARE stmt1 AS SELECT version();
EXEC SQL DECLARE cur1 CURSOR FOR stmt1;
```

Compatibility

`DECLARE` is specified in the SQL standard.

See Also

OPEN, CLOSE, DECLARE

DESCRIBE

Name

DESCRIBE — obtain information about a prepared statement or result set

Synopsis

```
DESCRIBE [ OUTPUT ] prepared_name USING [ SQL ] DESCRIPTOR descriptor_name
DESCRIBE [ OUTPUT ] prepared_name INTO [ SQL ] DESCRIPTOR descriptor_name
DESCRIBE [ OUTPUT ] prepared_name INTO sqlda_name
```

Description

DESCRIBE retrieves metadata information about the result columns contained in a prepared statement, without actually fetching a row.

Parameters

prepared_name

The name of a prepared statement. This can be an SQL identifier or a host variable.

descriptor_name

A descriptor name. It is case sensitive. It can be an SQL identifier or a host variable.

sqlda_name

The name of an SQLDA variable.

Examples

```
EXEC SQL ALLOCATE DESCRIPTOR mydesc;
EXEC SQL PREPARE stmt1 FROM :sql_stmt;
EXEC SQL DESCRIBE stmt1 INTO SQL DESCRIPTOR mydesc;
EXEC SQL GET DESCRIPTOR mydesc VALUE 1 :charvar = NAME;
EXEC SQL DEALLOCATE DESCRIPTOR mydesc;
```

Compatibility

DESCRIBE is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

DISCONNECT

Name

DISCONNECT — terminate a database connection

Synopsis

```
DISCONNECT connection_name
DISCONNECT [ CURRENT ]
DISCONNECT DEFAULT
DISCONNECT ALL
```

Description

DISCONNECT closes a connection (or all connections) to the database.

Parameters

connection_name

A database connection name established by the CONNECT command.

CURRENT

Close the "current" connection, which is either the most recently opened connection, or the connection set by the SET CONNECTION command. This is also the default if no argument is given to the DISCONNECT command.

DEFAULT

Close the default connection.

ALL

Close all open connections.

Examples

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS DEFAULT USER testuser;
    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL CONNECT TO testdb AS con2 USER testuser;
    EXEC SQL CONNECT TO testdb AS con3 USER testuser;

    EXEC SQL DISCONNECT CURRENT;  /* close con3          */
    EXEC SQL DISCONNECT DEFAULT;  /* close DEFAULT       */
    EXEC SQL DISCONNECT ALL;      /* close con2 and con1 */

    return 0;
```

```
}
```

Compatibility

`DISCONNECT` is specified in the SQL standard.

See Also

CONNECT, SET CONNECTION

EXECUTE IMMEDIATE

Name

`EXECUTE IMMEDIATE` — dynamically prepare and execute a statement

Synopsis

`EXECUTE IMMEDIATE` *`string`*

Description

`EXECUTE IMMEDIATE` immediately prepares and executes a dynamically specified SQL statement, without retrieving result rows.

Parameters

`string`

A literal C string or a host variable containing the SQL statement to be executed.

Examples

Here is an example that executes an `INSERT` statement using `EXECUTE IMMEDIATE` and a host variable named `command`:

```
sprintf(command, "INSERT INTO test (name, amount, letter) VALUES ('db: ”r1”', 1, 'f')");
EXEC SQL EXECUTE IMMEDIATE :command;
```

Compatibility

`EXECUTE IMMEDIATE` is specified in the SQL standard.

GET DESCRIPTOR

Name

`GET DESCRIPTOR` — get information from an SQL descriptor area

Synopsis

```
GET DESCRIPTOR descriptor_name :cvariable = descriptor_header_item [, ... ]
GET DESCRIPTOR descriptor_name VALUE column_number :cvariable = descriptor_item [, ... ]
```

Description

`GET DESCRIPTOR` retrieves information about a query result set from an SQL descriptor area and stores it into host variables. A descriptor area is typically populated using `FETCH` or `SELECT` before using this command to transfer the information into host language variables.

This command has two forms: The first form retrieves descriptor "header" items, which apply to the result set in its entirety. One example is the row count. The second form, which requires the column number as additional parameter, retrieves information about a particular column. Examples are the column name and the actual column value.

Parameters

descriptor_name

A descriptor name.

descriptor_header_item

A token identifying which header information item to retrieve. Only `COUNT`, to get the number of columns in the result set, is currently supported.

column_number

The number of the column about which information is to be retrieved. The count starts at 1.

descriptor_item

A token identifying which item of information about a column to retrieve. See Section 33.7.1 for a list of supported items.

cvariable

A host variable that will receive the data retrieved from the descriptor area.

Examples

An example to retrieve the number of columns in a result set:

```
EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
```

An example to retrieve a data length in the first column:

```
EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length = RETURNED_OCTET_LENGTH;
```

An example to retrieve the data body of the second column as a string:

```
EXEC SQL GET DESCRIPTOR d VALUE 2 :d_data = DATA;
```

Here is an example for a whole procedure of executing `SELECT current_database();` and showing the number of columns, the column data length, and the column data:

```
int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    int  d_count;
    char d_data[1024];
    int  d_returned_octet_length;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1 USER testuser;
    EXEC SQL ALLOCATE DESCRIPTOR d;

    /* Declare, open a cursor, and assign a descriptor to the cursor  */
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database();
    EXEC SQL OPEN cur;
    EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;

    /* Get a number of total columns */
    EXEC SQL GET DESCRIPTOR d :d_count = COUNT;
    printf("d_count                 = %d\n", d_count);

    /* Get length of a returned column */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_returned_octet_length = RETURNED_OCTET_LENGTH;
    printf("d_returned_octet_length = %d\n", d_returned_octet_length);

    /* Fetch the returned column as a string */
    EXEC SQL GET DESCRIPTOR d VALUE 1 :d_data = DATA;
    printf("d_data                  = %s\n", d_data);

    /* Closing */
    EXEC SQL CLOSE cur;
    EXEC SQL COMMIT;

    EXEC SQL DEALLOCATE DESCRIPTOR d;
    EXEC SQL DISCONNECT ALL;

    return 0;
}
```

When the example is executed, the result will look like this:

```
d_count                 = 1
d_returned_octet_length = 6
d_data                  = testdb
```

Compatibility

`GET DESCRIPTOR` is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, SET DESCRIPTOR

OPEN

Name

OPEN — open a dynamic cursor

Synopsis

```
OPEN cursor_name
OPEN cursor_name USING value [, ... ]
OPEN cursor_name USING SQL DESCRIPTOR descriptor_name
```

Description

OPEN opens a cursor and optionally binds actual values to the placeholders in the cursor's declaration. The cursor must previously have been declared with the DECLARE command. The execution of OPEN causes the query to start executing on the server.

Parameters

cursor_name

The name of the cursor to be opened. This can be an SQL identifier or a host variable.

value

A value to be bound to a placeholder in the cursor. This can be an SQL constant, a host variable, or a host variable with indicator.

descriptor_name

The name of a descriptor containing values to be bound to the placeholders in the cursor. This can be an SQL identifier or a host variable.

Examples

```
EXEC SQL OPEN a;
EXEC SQL OPEN d USING 1, 'test';
EXEC SQL OPEN c1 USING SQL DESCRIPTOR mydesc;
EXEC SQL OPEN :curname1;
```

Compatibility

OPEN is specified in the SQL standard.

See Also

DECLARE, CLOSE

PREPARE

Name

PREPARE — prepare a statement for execution

Synopsis

```
PREPARE name FROM string
```

Description

PREPARE prepares a statement dynamically specified as a string for execution. This is different from the direct SQL statement PREPARE, which can also be used in embedded programs. The EXECUTE command is used to execute either kind of prepared statement.

Parameters

prepared_name

An identifier for the prepared query.

string

A literal C string or a host variable containing a preparable statement, one of the SELECT, INSERT, UPDATE, or DELETE.

Examples

```
char *stmt = "SELECT * FROM test1 WHERE a = ? AND b = ?";

EXEC SQL ALLOCATE DESCRIPTOR outdesc;
EXEC SQL PREPARE foo FROM :stmt;

EXEC SQL EXECUTE foo USING SQL DESCRIPTOR indesc INTO SQL DESCRIPTOR outdesc;
```

Compatibility

PREPARE is specified in the SQL standard.

See Also

EXECUTE

SET AUTOCOMMIT

Name

`SET AUTOCOMMIT` — set the autocommit behavior of the current session

Synopsis

```
SET AUTOCOMMIT { = | TO } { ON | OFF }
```

Description

`SET AUTOCOMMIT` sets the autocommit behavior of the current database session. By default, embedded SQL programs are *not* in autocommit mode, so `COMMIT` needs to be issued explicitly when desired. This command can change the session to autocommit mode, where each individual statement is committed implicitly.

Compatibility

`SET AUTOCOMMIT` is an extension of PostgreSQL ECPG.

SET CONNECTION

Name

`SET CONNECTION` — select a database connection

Synopsis

```
SET CONNECTION [ TO | = ] connection_name
```

Description

`SET CONNECTION` sets the "current" database connection, which is the one that all commands use unless overridden.

Parameters

`connection_name`

A database connection name established by the `CONNECT` command.

`DEFAULT`

Set the connection to the default connection.

Examples

```
EXEC SQL SET CONNECTION TO con2;
EXEC SQL SET CONNECTION = con1;
```

Compatibility

`SET CONNECTION` is specified in the SQL standard.

See Also

CONNECT, DISCONNECT

SET DESCRIPTOR

Name

`SET DESCRIPTOR` — set information in an SQL descriptor area

Synopsis

```
SET DESCRIPTOR descriptor_name descriptor_header_item = value [, ... ]
SET DESCRIPTOR descriptor_name VALUE number descriptor_item = value [, ...]
```

Description

`SET DESCRIPTOR` populates an SQL descriptor area with values. The descriptor area is then typically used to bind parameters in a prepared query execution.

This command has two forms: The first form applies to the descriptor "header", which is independent of a particular datum. The second form assigns values to particular datums, identified by number.

Parameters

descriptor_name

A descriptor name.

descriptor_header_item

A token identifying which header information item to set. Only `COUNT`, to set the number of descriptor items, is currently supported.

number

The number of the descriptor item to set. The count starts at 1.

descriptor_item

A token identifying which item of information to set in the descriptor. See Section 33.7.1 for a list of supported items.

value

A value to store into the descriptor item. This can be an SQL constant or a host variable.

Examples

```
EXEC SQL SET DESCRIPTOR indesc COUNT = 1;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = 2;
EXEC SQL SET DESCRIPTOR indesc VALUE 1 DATA = :val1;
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val1, DATA = 'some string';
EXEC SQL SET DESCRIPTOR indesc VALUE 2 INDICATOR = :val2null, DATA = :val2;
```

Compatibility

`SET DESCRIPTOR` is specified in the SQL standard.

See Also

ALLOCATE DESCRIPTOR, GET DESCRIPTOR

TYPE

Name

`TYPE` — define a new data type

Synopsis

```
TYPE type_name IS ctype
```

Description

The `TYPE` command defines a new C type. It is equivalent to putting a `typedef` into a declare section.

This command is only recognized when `ecpg` is run with the `-c` option.

Parameters

type_name

The name for the new type. It must be a valid C type name.

ctype

A C type specification.

Examples

```
EXEC SQL TYPE customer IS
    struct
    {
        varchar name[50];
        int     phone;
    };

EXEC SQL TYPE cust_ind IS
    struct ind
    {
        short   name_ind;
        short   phone_ind;
    };

EXEC SQL TYPE c IS char reference;
EXEC SQL TYPE ind IS union { int integer; short smallint; };
EXEC SQL TYPE intarray IS int[AMOUNT];
EXEC SQL TYPE str IS varchar[BUFFERSIZ];
EXEC SQL TYPE string IS char[11];
```

Here is an example program that uses `EXEC SQL TYPE`:

```
EXEC SQL WHENEVER SQLERROR SQLPRINT;
```

```
EXEC SQL TYPE tt IS
    struct
    {
        varchar v[256];
        int     i;
    };

EXEC SQL TYPE tt_ind IS
    struct ind {
        short   v_ind;
        short   i_ind;
    };

int
main(void)
{
EXEC SQL BEGIN DECLARE SECTION;
    tt t;
    tt_ind t_ind;
EXEC SQL END DECLARE SECTION;

    EXEC SQL CONNECT TO testdb AS con1;

    EXEC SQL SELECT current_database(), 256 INTO :t:t_ind LIMIT 1;

    printf("t.v = %s\n", t.v.arr);
    printf("t.i = %d\n", t.i);

    printf("t_ind.v_ind = %d\n", t_ind.v_ind);
    printf("t_ind.i_ind = %d\n", t_ind.i_ind);

    EXEC SQL DISCONNECT con1;

    return 0;
}
```

The output from this program looks like this:

```
t.v = testdb
t.i = 256
t_ind.v_ind = 0
t_ind.i_ind = 0
```

Compatibility

The `TYPE` command is a PostgreSQL extension.

VAR

Name

VAR — define a variable

Synopsis

```
VAR varname IS ctype
```

Description

The VAR command assigns a new C data type to a host variable. The host variable must be previously declared in a declare section.

Parameters

varname

A C variable name.

ctype

A C type specification.

Examples

```
Exec sql begin declare section;
short a;
exec sql end declare section;
EXEC SQL VAR a IS int;
```

Compatibility

The VAR command is a PostgreSQL extension.

WHENEVER

Name

WHENEVER — specify the action to be taken when an SQL statement causes a specific class condition to be raised

Synopsis

```
WHENEVER { NOT FOUND | SQLERROR | SQLWARNING } action
```

Description

Define a behavior which is called on the special cases (Rows not found, SQL warnings or errors) in the result of SQL execution.

Parameters

See Section 33.8.1 for a description of the parameters.

Examples

```
EXEC SQL WHENEVER NOT FOUND CONTINUE;
EXEC SQL WHENEVER NOT FOUND DO BREAK;
EXEC SQL WHENEVER SQLWARNING SQLPRINT;
EXEC SQL WHENEVER SQLWARNING DO warn();
EXEC SQL WHENEVER SQLERROR sqlprint;
EXEC SQL WHENEVER SQLERROR CALL print2();
EXEC SQL WHENEVER SQLERROR DO handle_error("select");
EXEC SQL WHENEVER SQLERROR DO sqlnotice(NULL, NONO);
EXEC SQL WHENEVER SQLERROR DO sqlprint();
EXEC SQL WHENEVER SQLERROR GOTO error_label;
EXEC SQL WHENEVER SQLERROR STOP;
```

A typical application is the use of `WHENEVER NOT FOUND BREAK` to handle looping through result sets:

```
int
main(void)
{
    EXEC SQL CONNECT TO testdb AS con1;
    EXEC SQL ALLOCATE DESCRIPTOR d;
    EXEC SQL DECLARE cur CURSOR FOR SELECT current_database(), 'hoge', 256;
    EXEC SQL OPEN cur;

    /* when end of result set reached, break out of while loop */
    EXEC SQL WHENEVER NOT FOUND DO BREAK;

    while (1)
    {
```

```
        EXEC SQL FETCH NEXT FROM cur INTO SQL DESCRIPTOR d;
        ...
    }

    EXEC SQL CLOSE cur;
    EXEC SQL COMMIT;

    EXEC SQL DEALLOCATE DESCRIPTOR d;
    EXEC SQL DISCONNECT ALL;

    return 0;
}
```

Compatibility

`WHENEVER` is specified in the SQL standard, but most of the actions are PostgreSQL extensions.

33.15. Informix Compatibility Mode

`ecpg` can be run in a so-called *Informix compatibility mode*. If this mode is active, it tries to behave as if it were the Informix precompiler for Informix E/SQL. Generally spoken this will allow you to use the dollar sign instead of the `EXEC SQL` primitive to introduce embedded SQL commands.:

```
$int j = 3;
$CONNECT TO :dbname;
$CREATE TABLE test(i INT PRIMARY KEY, j INT);
$INSERT INTO test(i, j) VALUES (7, :j);
$COMMIT;
```

> **Note:** There must not be any white space between the `$` and a following preprocessor directive, that is, `include`, `define`, `ifdef`, etc. Otherwise, the preprocessor will parse the token as a host variable.

There are two compatibility modes: `INFORMIX`, `INFORMIX_SE`

When linking programs that use this compatibility mode, remember to link against `libcompat` that is shipped with ECPG.

Besides the previously explained syntactic sugar, the Informix compatibility mode ports some functions for input, output and transformation of data as well as embedded SQL statements known from E/SQL to ECPG.

Informix compatibility mode is closely connected to the pgtypeslib library of ECPG. pgtypeslib maps SQL data types to data types within the C host program and most of the additional functions of the Informix compatibility mode allow you to operate on those C host program types. Note however that the extent of the compatibility is limited. It does not try to copy Informix behavior; it allows you to do more or less the same operations and gives you functions that have the same name and the same basic behavior but it is no drop-in replacement if you are using Informix at the moment. Moreover, some of the data types are different. For example, PostgreSQL's datetime and interval types do not know about ranges like for example `YEAR TO MINUTE` so you won't find support in ECPG for that either.

33.15.1. Additional Types

The Informix-special "string" pseudo-type for storing right-trimmed character string data is now supported in Informix-mode without using `typedef`. In fact, in Informix-mode, ECPG refuses to process source files that contain `typedef sometype string;`

```
EXEC SQL BEGIN DECLARE SECTION;
string userid; /* this variable will contain trimmed data */
EXEC SQL END DECLARE SECTION;

EXEC SQL FETCH MYCUR INTO :userid;
```

33.15.2. Additional/Missing Embedded SQL Statements

`CLOSE DATABASE`

This statement closes the current connection. In fact, this is a synonym for ECPG's `DISCONNECT CURRENT`.:

```
$CLOSE DATABASE;                /* close the current connection */
EXEC SQL CLOSE DATABASE;
```

`FREE cursor_name`

Due to the differences how ECPG works compared to Informix's ESQL/C (i.e. which steps are purely grammar transformations and which steps rely on the underlying run-time library) there is no `FREE cursor_name` statement in ECPG. This is because in ECPG, `DECLARE CURSOR` doesn't translate to a function call into the run-time library that uses to the cursor name. This means that there's no run-time bookkeeping of SQL cursors in the ECPG run-time library, only in the PostgreSQL server.

`FREE statement_name`

`FREE statement_name` is a synonym for `DEALLOCATE PREPARE statement_name`.

33.15.3. Informix-compatible SQLDA Descriptor Areas

Informix-compatible mode supports a different structure than the one described in Section 33.7.2. See below:

```
struct sqlvar_compat
{
    short   sqltype;
    int     sqllen;
    char   *sqldata;
    short  *sqlind;
    char   *sqlname;
    char   *sqlformat;
    short   sqlitype;
    short   sqlilen;
    char   *sqlidata;
    int     sqlxid;
    char   *sqltypename;
    short   sqltypelen;
    short   sqlownerlen;
    short   sqlsourcetype;
    char   *sqlownername;
    int     sqlsourceid;
    char   *sqlilongdata;
    int     sqlflags;
    void   *sqlreserved;
};

struct sqlda_compat
{
    short  sqld;
    struct sqlvar_compat *sqlvar;
```

```
    char   desc_name[19];
    short  desc_occ;
    struct sqlda_compat *desc_next;
    void  *reserved;
};

typedef struct sqlvar_compat    sqlvar_t;
typedef struct sqlda_compat     sqlda_t;
```

The global properties are:

`sqld`

The number of fields in the `SQLDA` descriptor.

`sqlvar`

Pointer to the per-field properties.

`desc_name`

Unused, filled with zero-bytes.

`desc_occ`

Size of the allocated structure.

`desc_next`

Pointer to the next SQLDA structure if the result set contains more than one record.

`reserved`

Unused pointer, contains NULL. Kept for Informix-compatibility.

The per-field properties are below, they are stored in the `sqlvar` array:

`sqltype`

Type of the field. Constants are in `sqltypes.h`

`sqllen`

Length of the field data.

`sqldata`

Pointer to the field data. The pointer is of `char *` type, the data pointed by it is in a binary format. Example:

```
int intval;

switch (sqldata->sqlvar[i].sqltype)
{
    case SQLINTEGER:
        intval = *(int *)sqldata->sqlvar[i].sqldata;
        break;
  ...
}
```

`sqlind`

Pointer to the NULL indicator. If returned by DESCRIBE or FETCH then it's always a valid pointer. If used as input for `EXECUTE ... USING sqlda;` then NULL-pointer value means that the value for this field is non-NULL. Otherwise a valid pointer and `sqlitype` has to be properly set. Example:

```
if (*(int2 *)sqldata->sqlvar[i].sqlind != 0)
    printf("value is NULL\n");
```

`sqlname`

Name of the field. 0-terminated string.

`sqlformat`

Reserved in Informix, value of `PQfformat()` for the field.

`sqlitype`

Type of the NULL indicator data. It's always SQLSMINT when returning data from the server. When the `SQLDA` is used for a parametrized query, the data is treated according to the set type.

`sqlilen`

Length of the NULL indicator data.

`sqlxid`

Extended type of the field, result of `PQftype()`.

`sqltypename`
`sqltypelen`
`sqlownerlen`
`sqlsourcetype`
`sqlownername`
`sqlsourceid`
`sqlflags`
`sqlreserved`

Unused.

`sqlilongdata`

It equals to `sqldata` if `sqllen` is larger than 32KB.

Example:

```
EXEC SQL INCLUDE sqlda.h;

    sqlda_t        *sqlda; /* This doesn't need to be under embedded DECLARE SECTION */

    EXEC SQL BEGIN DECLARE SECTION;
    char *prep_stmt = "select * from table1";
    int i;
    EXEC SQL END DECLARE SECTION;

    ...

    EXEC SQL PREPARE mystmt FROM :prep_stmt;

    EXEC SQL DESCRIBE mystmt INTO sqlda;

    printf("# of fields: %d\n", sqlda->sqld);
```

```
for (i = 0; i < sqlda->sqld; i++)
  printf("field %d: \"%s\"\n", sqlda->sqlvar[i]->sqlname);

EXEC SQL DECLARE mycursor CURSOR FOR mystmt;
EXEC SQL OPEN mycursor;
EXEC SQL WHENEVER NOT FOUND GOTO out;

while (1)
{
  EXEC SQL FETCH mycursor USING sqlda;
}

EXEC SQL CLOSE mycursor;

free(sqlda); /* The main structure is all to be free(),
              * sqlda and sqlda->sqlvar is in one allocated area */
```

For more information, see the `sqlda.h` header and the `src/interfaces/ecpg/test/compat_informix/sqlda.pgc` regression test.

33.15.4. Additional Functions

`decadd`

Add two decimal type values.

```
int decadd(decimal *arg1, decimal *arg2, decimal *sum);
```

The function receives a pointer to the first operand of type decimal (`arg1`), a pointer to the second operand of type decimal (`arg2`) and a pointer to a value of type decimal that will contain the sum (`sum`). On success, the function returns 0. `ECPG_INFORMIX_NUM_OVERFLOW` is returned in case of overflow and `ECPG_INFORMIX_NUM_UNDERFLOW` in case of underflow. -1 is returned for other failures and `errno` is set to the respective `errno` number of the pgtypeslib.

`deccmp`

Compare two variables of type decimal.

```
int deccmp(decimal *arg1, decimal *arg2);
```

The function receives a pointer to the first decimal value (`arg1`), a pointer to the second decimal value (`arg2`) and returns an integer value that indicates which is the bigger value.

- 1, if the value that `arg1` points to is bigger than the value that `var2` points to
- -1, if the value that `arg1` points to is smaller than the value that `arg2` points to
- 0, if the value that `arg1` points to and the value that `arg2` points to are equal

`deccopy`

Copy a decimal value.

```
void deccopy(decimal *src, decimal *target);
```

The function receives a pointer to the decimal value that should be copied as the first argument (`src`) and a pointer to the target structure of type decimal (`target`) as the second argument.

`deccvasc`

Convert a value from its ASCII representation into a decimal type.

```
int deccvasc(char *cp, int len, decimal *np);
```

The function receives a pointer to string that contains the string representation of the number to be converted (`cp`) as well as its length `len`. `np` is a pointer to the decimal value that saves the result of the operation.

Valid formats are for example: `-2`, `.794`, `+3.44`, `592.49E07` or `-32.84e-4`.

The function returns 0 on success. If overflow or underflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` is returned. If the ASCII representation could not be parsed, `ECPG_INFORMIX_BAD_NUMERIC` is returned or `ECPG_INFORMIX_BAD_EXPONENT` if this problem occurred while parsing the exponent.

`deccvdbl`

Convert a value of type double to a value of type decimal.

```
int deccvdbl(double dbl, decimal *np);
```

The function receives the variable of type double that should be converted as its first argument (`dbl`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvint`

Convert a value of type int to a value of type decimal.

```
int deccvint(int in, decimal *np);
```

The function receives the variable of type int that should be converted as its first argument (`in`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`deccvlong`

Convert a value of type long to a value of type decimal.

```
int deccvlong(long lng, decimal *np);
```

The function receives the variable of type long that should be converted as its first argument (`lng`). As the second argument (`np`), the function receives a pointer to the decimal variable that should hold the result of the operation.

The function returns 0 on success and a negative value if the conversion failed.

`decdiv`

Divide two variables of type decimal.

```
int decdiv(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1`/`n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the division fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively. If an attempt to divide by zero is observed, the function returns `ECPG_INFORMIX_DIVIDE_ZERO`.

`decmul`

Multiply two decimal values.

```
int decmul(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1*n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the multiplication fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`decsub`

Subtract one decimal value from another.

```
int decsub(decimal *n1, decimal *n2, decimal *result);
```

The function receives pointers to the variables that are the first (`n1`) and the second (`n2`) operands and calculates `n1-n2`. `result` is a pointer to the variable that should hold the result of the operation.

On success, 0 is returned and a negative value if the subtraction fails. If overflow or underflow occurred, the function returns `ECPG_INFORMIX_NUM_OVERFLOW` or `ECPG_INFORMIX_NUM_UNDERFLOW` respectively.

`dectoasc`

Convert a variable of type decimal to its ASCII representation in a C char* string.

```
int dectoasc(decimal *np, char *cp, int len, int right)
```

The function receives a pointer to a variable of type decimal (`np`) that it converts to its textual representation. `cp` is the buffer that should hold the result of the operation. The parameter `right` specifies, how many digits right of the decimal point should be included in the output. The result will be rounded to this number of decimal digits. Setting `right` to -1 indicates that all available decimal digits should be included in the output. If the length of the output buffer, which is indicated by `len` is not sufficient to hold the textual representation including the trailing zero byte, only a single `*` character is stored in the result and -1 is returned.

The function returns either -1 if the buffer `cp` was too small or `ECPG_INFORMIX_OUT_OF_MEMORY` if memory was exhausted.

`dectodbl`

Convert a variable of type decimal to a double.

```
int dectodbl(decimal *np, double *dblp);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the double variable that should hold the result of the operation (`dblp`).

On success, 0 is returned and a negative value if the conversion failed.

`dectoint`

Convert a variable to type decimal to an integer.

```
int dectoint(decimal *np, int *ip);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the integer variable that should hold the result of the operation (`ip`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits an integer to the range from -32767 to 32767, while the limits in the ECPG implementation depend on the architecture (`-INT_MAX .. INT_MAX`).

`dectolong`

Convert a variable to type decimal to a long integer.

```
int dectolong(decimal *np, long *lngp);
```

The function receives a pointer to the decimal value to convert (`np`) and a pointer to the long variable that should hold the result of the operation (`lngp`).

On success, 0 is returned and a negative value if the conversion failed. If an overflow occurred, `ECPG_INFORMIX_NUM_OVERFLOW` is returned.

Note that the ECPG implementation differs from the Informix implementation. Informix limits a long integer to the range from -2,147,483,647 to 2,147,483,647, while the limits in the ECPG implementation depend on the architecture (`-LONG_MAX .. LONG_MAX`).

`rdatestr`

Converts a date to a C char* string.

```
int rdatestr(date d, char *str);
```

The function receives two arguments, the first one is the date to convert (`d` and the second one is a pointer to the target string. The output format is always `yyyy-mm-dd`, so you need to allocate at least 11 bytes (including the zero-byte terminator) for the string.

The function returns 0 on success and a negative value in case of error.

Note that ECPG's implementation differs from the Informix implementation. In Informix the format can be influenced by setting environment variables. In ECPG however, you cannot change the output format.

`rstrdate`

Parse the textual representation of a date.

```
int rstrdate(char *str, date *d);
```

The function receives the textual representation of the date to convert (`str`) and a pointer to a variable of type date (`d`). This function does not allow you to specify a format mask. It uses the default format mask of Informix which is `mm/dd/yyyy`. Internally, this function is implemented by means of `rdefmtdate`. Therefore, `rstrdate` is not faster and if you have the choice you should opt for `rdefmtdate` which allows you to specify the format mask explicitly.

The function returns the same values as `rdefmtdate`.

`rtoday`

Get the current date.

```
void rtoday(date *d);
```

The function receives a pointer to a date variable (`d`) that it sets to the current date.

Internally this function uses the *`PGTYPESdate_today`* function.

`rjulmdy`

Extract the values for the day, the month and the year from a variable of type date.

```
int rjulmdy(date d, short mdy[3]);
```

The function receives the date `d` and a pointer to an array of 3 short integer values `mdy`. The variable name indicates the sequential order: `mdy[0]` will be set to contain the number of the month, `mdy[1]` will be set to the value of the day and `mdy[2]` will contain the year.

The function always returns 0 at the moment.

Internally the function uses the *PGTYPESdate_julmdy* function.

rdefmtdate

Use a format mask to convert a character string to a value of type date.

```
int rdefmtdate(date *d, char *fmt, char *str);
```

The function receives a pointer to the date value that should hold the result of the operation (d), the format mask to use for parsing the date (fmt) and the C char* string containing the textual representation of the date (str). The textual representation is expected to match the format mask. However you do not need to have a 1:1 mapping of the string to the format mask. The function only analyzes the sequential order and looks for the literals yy or yyyy that indicate the position of the year, mm to indicate the position of the month and dd to indicate the position of the day.

The function returns the following values:

- 0 - The function terminated successfully.
- ECPG_INFORMIX_ENOSHORTDATE - The date does not contain delimiters between day, month and year. In this case the input string must be exactly 6 or 8 bytes long but isn't.
- ECPG_INFORMIX_ENOTDMY - The format string did not correctly indicate the sequential order of year, month and day.
- ECPG_INFORMIX_BAD_DAY - The input string does not contain a valid day.
- ECPG_INFORMIX_BAD_MONTH - The input string does not contain a valid month.
- ECPG_INFORMIX_BAD_YEAR - The input string does not contain a valid year.

Internally this function is implemented to use the *PGTYPESdate_defmt_asc* function. See the reference there for a table of example input.

rfmtdate

Convert a variable of type date to its textual representation using a format mask.

```
int rfmtdate(date d, char *fmt, char *str);
```

The function receives the date to convert (d), the format mask (fmt) and the string that will hold the textual representation of the date (str).

On success, 0 is returned and a negative value if an error occurred.

Internally this function uses the *PGTYPESdate_fmt_asc* function, see the reference there for examples.

rmdyjul

Create a date value from an array of 3 short integers that specify the day, the month and the year of the date.

```
int rmdyjul(short mdy[3], date *d);
```

The function receives the array of the 3 short integers (mdy) and a pointer to a variable of type date that should hold the result of the operation.

Currently the function returns always 0.

Internally the function is implemented to use the function *PGTYPESdate_mdyjul*.

rdayofweek

Return a number representing the day of the week for a date value.

```
int rdayofweek(date d);
```

The function receives the date variable `d` as its only argument and returns an integer that indicates the day of the week for this date.

- 0 - Sunday
- 1 - Monday
- 2 - Tuesday
- 3 - Wednesday
- 4 - Thursday
- 5 - Friday
- 6 - Saturday

Internally the function is implemented to use the function *`PGTYPESdate_dayofweek`*.

`dtcurrent`

Retrieve the current timestamp.

```
void dtcurrent(timestamp *ts);
```

The function retrieves the current timestamp and saves it into the timestamp variable that `ts` points to.

`dtcvasc`

Parses a timestamp from its textual representation into a timestamp variable.

```
int dtcvasc(char *str, timestamp *ts);
```

The function receives the string to parse (`str`) and a pointer to the timestamp variable that should hold the result of the operation (`ts`).

The function returns 0 on success and a negative value in case of error.

Internally this function uses the *`PGTYPEStimestamp_from_asc`* function. See the reference there for a table with example inputs.

`dtcvfmtasc`

Parses a timestamp from its textual representation using a format mask into a timestamp variable.

```
dtcvfmtasc(char *inbuf, char *fmtstr, timestamp *dtvalue)
```

The function receives the string to parse (`inbuf`), the format mask to use (`fmtstr`) and a pointer to the timestamp variable that should hold the result of the operation (`dtvalue`).

This function is implemented by means of the *`PGTYPEStimestamp_defmt_asc`* function. See the documentation there for a list of format specifiers that can be used.

The function returns 0 on success and a negative value in case of error.

`dtsub`

Subtract one timestamp from another and return a variable of type interval.

```
int dtsub(timestamp *ts1, timestamp *ts2, interval *iv);
```

The function will subtract the timestamp variable that `ts2` points to from the timestamp variable that `ts1` points to and will store the result in the interval variable that `iv` points to.

Upon success, the function returns 0 and a negative value if an error occurred.

`dttoasc`

Convert a timestamp variable to a C char* string.

```
int dttoasc(timestamp *ts, char *output);
```

The function receives a pointer to the timestamp variable to convert (`ts`) and the string that should hold the result of the operation `output`). It converts `ts` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

`dttofmtasc`

Convert a timestamp variable to a C char* using a format mask.

```
int dttofmtasc(timestamp *ts, char *output, int str_len, char *fmtstr);
```

The function receives a pointer to the timestamp to convert as its first argument (`ts`), a pointer to the output buffer (`output`), the maximal length that has been allocated for the output buffer (`str_len`) and the format mask to use for the conversion (`fmtstr`).

Upon success, the function returns 0 and a negative value if an error occurred.

Internally, this function uses the *`PGTYPEStimestamp_fmt_asc`* function. See the reference there for information on what format mask specifiers can be used.

`intoasc`

Convert an interval variable to a C char* string.

```
int intoasc(interval *i, char *str);
```

The function receives a pointer to the interval variable to convert (`i`) and the string that should hold the result of the operation `str`). It converts `i` to its textual representation according to the SQL standard, which is be `YYYY-MM-DD HH:MM:SS`.

Upon success, the function returns 0 and a negative value if an error occurred.

`rfmtlong`

Convert a long integer value to its textual representation using a format mask.

```
int rfmtlong(long lng_val, char *fmt, char *outbuf);
```

The function receives the long value `lng_val`, the format mask `fmt` and a pointer to the output buffer `outbuf`. It converts the long value according to the format mask to its textual representation.

The format mask can be composed of the following format specifying characters:

- `*` (asterisk) - if this position would be blank otherwise, fill it with an asterisk.
- `&` (ampersand) - if this position would be blank otherwise, fill it with a zero.
- `#` - turn leading zeroes into blanks.
- `<` - left-justify the number in the string.
- `,` (comma) - group numbers of four or more digits into groups of three digits separated by a comma.
- `.` (period) - this character separates the whole-number part of the number from the fractional part.
- `-` (minus) - the minus sign appears if the number is a negative value.
- `+` (plus) - the plus sign appears if the number is a positive value.
- `(` - this replaces the minus sign in front of the negative number. The minus sign will not appear.
- `)` - this character replaces the minus and is printed behind the negative value.
- `$` - the currency symbol.

`rupshift`

Convert a string to upper case.

```
void rupshift(char *str);
```

The function receives a pointer to the string and transforms every lower case character to upper case.

`byleng`

Return the number of characters in a string without counting trailing blanks.

```
int byleng(char *str, int len);
```

The function expects a fixed-length string as its first argument (`str`) and its length as its second argument (`len`). It returns the number of significant characters, that is the length of the string without trailing blanks.

`ldchar`

Copy a fixed-length string into a null-terminated string.

```
void ldchar(char *src, int len, char *dest);
```

The function receives the fixed-length string to copy (`src`), its length (`len`) and a pointer to the destination memory (`dest`). Note that you need to reserve at least `len+1` bytes for the string that `dest` points to. The function copies at most `len` bytes to the new location (less if the source string has trailing blanks) and adds the null-terminator.

`rgetmsg`

```
int rgetmsg(int msgnum, char *s, int maxsize);
```

This function exists but is not implemented at the moment!

`rtypalign`

```
int rtypalign(int offset, int type);
```

This function exists but is not implemented at the moment!

`rtypmsize`

```
int rtypmsize(int type, int len);
```

This function exists but is not implemented at the moment!

`rtypwidth`

```
int rtypwidth(int sqltype, int sqllen);
```

This function exists but is not implemented at the moment!

`rsetnull`

Set a variable to NULL.

```
int rsetnull(int t, char *ptr);
```

The function receives an integer that indicates the type of the variable and a pointer to the variable itself that is cast to a C char* pointer.

The following types exist:

- `CCHARTYPE` - For a variable of type `char` or `char*`
- `CSHORTTYPE` - For a variable of type `short int`
- `CINTTYPE` - For a variable of type `int`
- `CBOOLTYPE` - For a variable of type `boolean`
- `CFLOATTYPE` - For a variable of type `float`

- `CLONGTYPE` - For a variable of type `long`
- `CDOUBLETYPE` - For a variable of type `double`
- `CDECIMALTYPE` - For a variable of type `decimal`
- `CDATETYPE` - For a variable of type `date`
- `CDTIMETYPE` - For a variable of type `timestamp`

Here is an example of a call to this function:

```
$char c[] = "abc       ";
$short s = 17;
$int i = -74874;

rsetnull(CCHARTYPE, (char *) c);
rsetnull(CSHORTTYPE, (char *) &s);
rsetnull(CINTTYPE, (char *) &i);
```

`risnull`

Test if a variable is NULL.

```
int risnull(int t, char *ptr);
```

The function receives the type of the variable to test (`t`) as well a pointer to this variable (`ptr`). Note that the latter needs to be cast to a char*. See the function *`rsetnull`* for a list of possible variable types.

Here is an example of how to use this function:

```
$char c[] = "abc       ";
$short s = 17;
$int i = -74874;

risnull(CCHARTYPE, (char *) c);
risnull(CSHORTTYPE, (char *) &s);
risnull(CINTTYPE, (char *) &i);
```

33.15.5. Additional Constants

Note that all constants here describe errors and all of them are defined to represent negative values. In the descriptions of the different constants you can also find the value that the constants represent in the current implementation. However you should not rely on this number. You can however rely on the fact all of them are defined to represent negative values.

`ECPG_INFORMIX_NUM_OVERFLOW`

Functions return this value if an overflow occurred in a calculation. Internally it is defined as -1200 (the Informix definition).

`ECPG_INFORMIX_NUM_UNDERFLOW`

Functions return this value if an underflow occurred in a calculation. Internally it is defined as -1201 (the Informix definition).

`ECPG_INFORMIX_DIVIDE_ZERO`

Functions return this value if an attempt to divide by zero is observed. Internally it is defined as -1202 (the Informix definition).

`ECPG_INFORMIX_BAD_YEAR`

Functions return this value if a bad value for a year was found while parsing a date. Internally it is defined as -1204 (the Informix definition).

`ECPG_INFORMIX_BAD_MONTH`

Functions return this value if a bad value for a month was found while parsing a date. Internally it is defined as -1205 (the Informix definition).

`ECPG_INFORMIX_BAD_DAY`

Functions return this value if a bad value for a day was found while parsing a date. Internally it is defined as -1206 (the Informix definition).

`ECPG_INFORMIX_ENOSHORTDATE`

Functions return this value if a parsing routine needs a short date representation but did not get the date string in the right length. Internally it is defined as -1209 (the Informix definition).

`ECPG_INFORMIX_DATE_CONVERT`

Functions return this value if an error occurred during date formatting. Internally it is defined as -1210 (the Informix definition).

`ECPG_INFORMIX_OUT_OF_MEMORY`

Functions return this value if memory was exhausted during their operation. Internally it is defined as -1211 (the Informix definition).

`ECPG_INFORMIX_ENOTDMY`

Functions return this value if a parsing routine was supposed to get a format mask (like `mmddyy`) but not all fields were listed correctly. Internally it is defined as -1212 (the Informix definition).

`ECPG_INFORMIX_BAD_NUMERIC`

Functions return this value either if a parsing routine cannot parse the textual representation for a numeric value because it contains errors or if a routine cannot complete a calculation involving numeric variables because at least one of the numeric variables is invalid. Internally it is defined as -1213 (the Informix definition).

`ECPG_INFORMIX_BAD_EXPONENT`

Functions return this value if a parsing routine cannot parse an exponent. Internally it is defined as -1216 (the Informix definition).

`ECPG_INFORMIX_BAD_DATE`

Functions return this value if a parsing routine cannot parse a date. Internally it is defined as -1218 (the Informix definition).

`ECPG_INFORMIX_EXTRA_CHARS`

Functions return this value if a parsing routine is passed extra characters it cannot parse. Internally it is defined as -1264 (the Informix definition).

33.16. Internals

This section explains how ECPG works internally. This information can occasionally be useful to help users understand how to use ECPG.

The first four lines written by `ecpg` to the output are fixed lines. Two are comments and two are include lines necessary to interface to the library. Then the preprocessor reads through the file and writes output. Normally it just echoes everything to the output.

When it sees an `EXEC SQL` statement, it intervenes and changes it. The command starts with `EXEC SQL` and ends with `;`. Everything in between is treated as an SQL statement and parsed for variable substitution.

Variable substitution occurs when a symbol starts with a colon (`:`). The variable with that name is looked up among the variables that were previously declared within a `EXEC SQL DECLARE` section.

The most important function in the library is `ECPGdo`, which takes care of executing most commands. It takes a variable number of arguments. This can easily add up to 50 or so arguments, and we hope this will not be a problem on any platform.

The arguments are:

A line number

This is the line number of the original line; used in error messages only.

A string

This is the SQL command that is to be issued. It is modified by the input variables, i.e., the variables that where not known at compile time but are to be entered in the command. Where the variables should go the string contains `?`.

Input variables

Every input variable causes ten arguments to be created. (See below.)

`ECPGt_EOIT`

An `enum` telling that there are no more input variables.

Output variables

Every output variable causes ten arguments to be created. (See below.) These variables are filled by the function.

`ECPGt_EORT`

An `enum` telling that there are no more variables.

For every variable that is part of the SQL command, the function gets ten arguments:

1. The type as a special symbol.
2. A pointer to the value or a pointer to the pointer.
3. The size of the variable if it is a `char` or `varchar`.
4. The number of elements in the array (for array fetches).
5. The offset to the next element in the array (for array fetches).
6. The type of the indicator variable as a special symbol.
7. A pointer to the indicator variable.

8. 0
9. The number of elements in the indicator array (for array fetches).
10. The offset to the next element in the indicator array (for array fetches).

Note that not all SQL commands are treated in this way. For instance, an open cursor statement like:

```
EXEC SQL OPEN cursor;
```

is not copied to the output. Instead, the cursor's `DECLARE` command is used at the position of the `OPEN` command because it indeed opens the cursor.

Here is a complete example describing the output of the preprocessor of a file `foo.pgc` (details might change with each particular version of the preprocessor):

```
EXEC SQL BEGIN DECLARE SECTION;
int index;
int result;
EXEC SQL END DECLARE SECTION;
...
EXEC SQL SELECT res INTO :result FROM mytable WHERE index = :index;
```

is translated into:

```
/* Processed by ecpg (2.6.0) */
/* These two include files are added by the preprocessor */
#include <ecpgtype.h>;
#include <ecpglib.h>;

/* exec sql begin declare section */

#line 1 "foo.pgc"

 int index;
 int result;
/* exec sql end declare section */
...
ECPGdo(__LINE__, NULL, "SELECT res FROM mytable WHERE index = ?     ",
        ECPGt_int,&(index),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EOIT,
        ECPGt_int,&(result),1L,1L,sizeof(int),
        ECPGt_NO_INDICATOR, NULL , 0L, 0L, 0L, ECPGt_EORT);
#line 147 "foo.pgc"
```

(The indentation here is added for readability and not something the preprocessor does.)

Chapter 34. The Information Schema

The information schema consists of a set of views that contain information about the objects defined in the current database. The information schema is defined in the SQL standard and can therefore be expected to be portable and remain stable — unlike the system catalogs, which are specific to PostgreSQL and are modeled after implementation concerns. The information schema views do not, however, contain information about PostgreSQL-specific features; to inquire about those you need to query the system catalogs or other PostgreSQL-specific views.

> **Note:** When querying the database for constraint information, it is possible for a standard-compliant query that expects to return one row to return several. This is because the SQL standard requires constraint names to be unique within a schema, but PostgreSQL does not enforce this restriction. PostgreSQL automatically-generated constraint names avoid duplicates in the same schema, but users can specify such duplicate names.
>
> This problem can appear when querying information schema views such as `check_constraint_routine_usage`, `check_constraints`, `domain_constraints`, and `referential_constraints`. Some other views have similar issues but contain the table name to help distinguish duplicate rows, e.g., `constraint_column_usage`, `constraint_table_usage`, `table_constraints`.

34.1. The Schema

The information schema itself is a schema named `information_schema`. This schema automatically exists in all databases. The owner of this schema is the initial database user in the cluster, and that user naturally has all the privileges on this schema, including the ability to drop it (but the space savings achieved by that are minuscule).

By default, the information schema is not in the schema search path, so you need to access all objects in it through qualified names. Since the names of some of the objects in the information schema are generic names that might occur in user applications, you should be careful if you want to put the information schema in the path.

34.2. Data Types

The columns of the information schema views use special data types that are defined in the information schema. These are defined as simple domains over ordinary built-in types. You should not use these types for work outside the information schema, but your applications must be prepared for them if they select from the information schema.

These types are:

`cardinal_number`

A nonnegative integer.

`character_data`

A character string (without specific maximum length).

`sql_identifier`

A character string. This type is used for SQL identifiers, the type `character_data` is used for any other kind of text data.

`time_stamp`

A domain over the type `timestamp with time zone`

`yes_or_no`

A character string domain that contains either `YES` or `NO`. This is used to represent Boolean (true/false) data in the information schema. (The information schema was invented before the type `boolean` was added to the SQL standard, so this convention is necessary to keep the information schema backward compatible.)

Every column in the information schema has one of these five types.

34.3. `information_schema_catalog_name`

`information_schema_catalog_name` is a table that always contains one row and one column containing the name of the current database (current catalog, in SQL terminology).

Table 34-1. `information_schema_catalog_name` Columns

Name	Data Type	Description
`catalog_name`	`sql_identifier`	Name of the database that contains this information schema

34.4. `administrable_role_authorizations`

The view `administrable_role_authorizations` identifies all roles that the current user has the admin option for.

Table 34-2. `administrable_role_authorizations` Columns

Name	Data Type	Description
`grantee`	`sql_identifier`	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
`role_name`	`sql_identifier`	Name of a role
`is_grantable`	`yes_or_no`	Always `YES`

34.5. `applicable_roles`

The view `applicable_roles` identifies all roles whose privileges the current user can use. This

means there is some chain of role grants from the current user to the role in question. The current user itself is also an applicable role. The set of applicable roles is generally used for permission checking.

Table 34-3. `applicable_roles` Columns

Name	Data Type	Description
`grantee`	`sql_identifier`	Name of the role to which this role membership was granted (can be the current user, or a different role in case of nested role memberships)
`role_name`	`sql_identifier`	Name of a role
`is_grantable`	`yes_or_no`	`YES` if the grantee has the admin option on the role, `NO` if not

34.6. `attributes`

The view `attributes` contains information about the attributes of composite data types defined in the database. (Note that the view does not give information about table columns, which are sometimes called attributes in PostgreSQL contexts.) Only those attributes are shown that the current user has access to (by way of being the owner of or having some privilege on the type).

Table 34-4. `attributes` Columns

Name	Data Type	Description
`udt_catalog`	`sql_identifier`	Name of the database containing the data type (always the current database)
`udt_schema`	`sql_identifier`	Name of the schema containing the data type
`udt_name`	`sql_identifier`	Name of the data type
`attribute_name`	`sql_identifier`	Name of the attribute
`ordinal_position`	`cardinal_number`	Ordinal position of the attribute within the data type (count starts at 1)
`attribute_default`	`character_data`	Default expression of the attribute
`is_nullable`	`yes_or_no`	`YES` if the attribute is possibly nullable, `NO` if it is known not nullable.

Name	Data Type	Description
data_type	character_data	Data type of the attribute, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in attribute_udt_name and associated columns).
character_maximum_length	cardinal_number	If data_type identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length	cardinal_number	If data_type identifies a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the attribute (always the current database), null if default or the data type of the attribute is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the attribute, null if default or the data type of the attribute is not collatable
collation_name	sql_identifier	Name of the collation of the attribute, null if default or the data type of the attribute is not collatable

Name	Data Type	Description
numeric_precision	cardinal_number	If data_type identifies a numeric type, this column contains the (declared or implicit) precision of the type for this attribute. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
numeric_precision_radix	cardinal_number	If data_type identifies a numeric type, this column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale	cardinal_number	If data_type identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this attribute. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
datetime_precision	cardinal_number	If data_type identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this attribute, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.

Name	Data Type	Description
interval_type	character_data	If data_type identifies an interval type, this column contains the specification which fields the intervals include for this attribute, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL (see datetime_precision for the fractional seconds precision of interval type attributes)
attribute_udt_catalog	sql_identifier	Name of the database that the attribute data type is defined in (always the current database)
attribute_udt_schema	sql_identifier	Name of the schema that the attribute data type is defined in
attribute_udt_name	sql_identifier	Name of the attribute data type
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
is_derived_reference_attribute	yes_or_no	Applies to a feature not available in PostgreSQL

See also under Section 34.16, a similarly structured view, for further information on some of the

columns.

34.7. character_sets

The view character_sets identifies the character sets available in the current database. Since PostgreSQL does not support multiple character sets within one database, this view only shows one, which is the database encoding.

Take note of how the following terms are used in the SQL standard:

character repertoire

An abstract collection of characters, for example UNICODE, UCS, or LATIN1. Not exposed as an SQL object, but visible in this view.

character encoding form

An encoding of some character repertoire. Most older character repertoires only use one encoding form, and so there are no separate names for them (e.g., LATIN1 is an encoding form applicable to the LATIN1 repertoire). But for example Unicode has the encoding forms UTF8, UTF16, etc. (not all supported by PostgreSQL). Encoding forms are not exposed as an SQL object, but are visible in this view.

character set

A named SQL object that identifies a character repertoire, a character encoding, and a default collation. A predefined character set would typically have the same name as an encoding form, but users could define other names. For example, the character set UTF8 would typically identify the character repertoire UCS, encoding form UTF8, and some default collation.

You can think of an "encoding" in PostgreSQL either as a character set or a character encoding form. They will have the same name, and there can only be one in one database.

Table 34-5. character_sets Columns

Name	Data Type	Description
character_set_catalog	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null.
character_set_schema	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null.
character_set_name	sql_identifier	Name of the character set, currently implemented as showing the name of the database encoding
character_repertoire	sql_identifier	Character repertoire, showing UCS if the encoding is UTF8, else just the encoding name
form_of_use	sql_identifier	Character encoding form, same as the database encoding

Name	Data Type	Description
default_collate_catalog	sql_identifier	Name of the database containing the default collation (always the current database, if any collation is identified)
default_collate_schema	sql_identifier	Name of the schema containing the default collation
default_collate_name	sql_identifier	Name of the default collation. The default collation is identified as the collation that matches the COLLATE and CTYPE settings of the current database. If there is no such collation, then this column and the associated schema and catalog columns are null.

34.8. check_constraint_routine_usage

The view check_constraint_routine_usage identifies routines (functions and procedures) that are used by a check constraint. Only those routines are shown that are owned by a currently enabled role.

Table 34-6. check_constraint_routine_usage Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema containing the constraint
constraint_name	sql_identifier	Name of the constraint
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The "specific name" of the function. See Section 34.40 for more information.

34.9. check_constraints

The view check_constraints contains all check constraints, either defined on a table or on a domain, that are owned by a currently enabled role. (The owner of the table or domain is the owner of the constraint.)

Table 34-7. `check_constraints` Columns

Name	Data Type	Description
`constraint_catalog`	`sql_identifier`	Name of the database containing the constraint (always the current database)
`constraint_schema`	`sql_identifier`	Name of the schema containing the constraint
`constraint_name`	`sql_identifier`	Name of the constraint
`check_clause`	`character_data`	The check expression of the check constraint

34.10. `collations`

The view `collations` contains the collations available in the current database.

Table 34-8. `collations` Columns

Name	Data Type	Description
`collation_catalog`	`sql_identifier`	Name of the database containing the collation (always the current database)
`collation_schema`	`sql_identifier`	Name of the schema containing the collation
`collation_name`	`sql_identifier`	Name of the default collation
`pad_attribute`	`character_data`	Always `NO PAD` (The alternative `PAD SPACE` is not supported by PostgreSQL.)

34.11. `collation_character_set_applicability`

The view `collation_character_set_applicability` identifies which character set the available collations are applicable to. In PostgreSQL, there is only one character set per database (see explanation in Section 34.7), so this view does not provide much useful information.

Table 34-9. `collation_character_set_applicability` Columns

Name	Data Type	Description
`collation_catalog`	`sql_identifier`	Name of the database containing the collation (always the current database)
`collation_schema`	`sql_identifier`	Name of the schema containing the collation
`collation_name`	`sql_identifier`	Name of the default collation

Name	Data Type	Description
character_set_catalog	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null
character_set_schema	sql_identifier	Character sets are currently not implemented as schema objects, so this column is null
character_set_name	sql_identifier	Name of the character set

34.12. column_domain_usage

The view column_domain_usage identifies all columns (of a table or a view) that make use of some domain defined in the current database and owned by a currently enabled role.

Table 34-10. column_domain_usage Columns

Name	Data Type	Description
domain_catalog	sql_identifier	Name of the database containing the domain (always the current database)
domain_schema	sql_identifier	Name of the schema containing the domain
domain_name	sql_identifier	Name of the domain
table_catalog	sql_identifier	Name of the database containing the table (always the current database)
table_schema	sql_identifier	Name of the schema containing the table
table_name	sql_identifier	Name of the table
column_name	sql_identifier	Name of the column

34.13. column_options

The view column_options contains all the options defined for foreign table columns in the current database. Only those foreign table columns are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-11. column_options Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the foreign table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the foreign table

Name	Data Type	Description
table_name	sql_identifier	Name of the foreign table
column_name	sql_identifier	Name of the column
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

34.14. column_privileges

The view column_privileges identifies all privileges granted on columns to a currently enabled role or by a currently enabled role. There is one row for each combination of column, grantor, and grantee.

If a privilege has been granted on an entire table, it will show up in this view as a grant for each column, but only for the privilege types where column granularity is possible: SELECT, INSERT, UPDATE, REFERENCES.

Table 34-12. column_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column
table_name	sql_identifier	Name of the table that contains the column
column_name	sql_identifier	Name of the column
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, or REFERENCES
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.15. column_udt_usage

The view column_udt_usage identifies all columns that use data types owned by a currently enabled role. Note that in PostgreSQL, built-in data types behave like user-defined types, so they are included here as well. See also Section 34.16 for details.

Table 34-13. `column_udt_usage` Columns

Name	Data Type	Description
`udt_catalog`	`sql_identifier`	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
`udt_schema`	`sql_identifier`	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in
`udt_name`	`sql_identifier`	Name of the column data type (the underlying type of the domain, if applicable)
`table_catalog`	`sql_identifier`	Name of the database containing the table (always the current database)
`table_schema`	`sql_identifier`	Name of the schema containing the table
`table_name`	`sql_identifier`	Name of the table
`column_name`	`sql_identifier`	Name of the column

34.16. `columns`

The view `columns` contains information about all table columns (or view columns) in the database. System columns (`oid`, etc.) are not included. Only those columns are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-14. `columns` Columns

Name	Data Type	Description
`table_catalog`	`sql_identifier`	Name of the database containing the table (always the current database)
`table_schema`	`sql_identifier`	Name of the schema containing the table
`table_name`	`sql_identifier`	Name of the table
`column_name`	`sql_identifier`	Name of the column
`ordinal_position`	`cardinal_number`	Ordinal position of the column within the table (count starts at 1)
`column_default`	`character_data`	Default expression of the column

Name	Data Type	Description
is_nullable	yes_or_no	YES if the column is possibly nullable, NO if it is known not nullable. A not-null constraint is one way a column can be known not nullable, but there can be others.
data_type	character_data	Data type of the column, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in udt_name and associated columns). If the column is based on a domain, this column refers to the type underlying the domain (and the domain is identified in domain_name and associated columns).
character_maximum_length	cardinal_number	If data_type identifies a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length	cardinal_number	If data_type identifies a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
numeric_precision	cardinal_number	If data_type identifies a numeric type, this column contains the (declared or implicit) precision of the type for this column. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.

Name	Data Type	Description
numeric_precision_radix	cardinal_number	If data_type identifies a numeric type, this column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale	cardinal_number	If data_type identifies an exact numeric type, this column contains the (declared or implicit) scale of the type for this column. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
datetime_precision	cardinal_number	If data_type identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this column, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.
interval_type	character_data	If data_type identifies an interval type, this column contains the specification which fields the intervals include for this column, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.

Name	Data Type	Description
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL (see datetime_precision for the fractional seconds precision of interval type columns)
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the column (always the current database), null if default or the data type of the column is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the column, null if default or the data type of the column is not collatable
collation_name	sql_identifier	Name of the collation of the column, null if default or the data type of the column is not collatable
domain_catalog	sql_identifier	If the column has a domain type, the name of the database that the domain is defined in (always the current database), else null.
domain_schema	sql_identifier	If the column has a domain type, the name of the schema that the domain is defined in, else null.
domain_name	sql_identifier	If the column has a domain type, the name of the domain, else null.
udt_catalog	sql_identifier	Name of the database that the column data type (the underlying type of the domain, if applicable) is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the column data type (the underlying type of the domain, if applicable) is defined in

Name	Data Type	Description
udt_name	sql_identifier	Name of the column data type (the underlying type of the domain, if applicable)
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the column, unique among the data type descriptors pertaining to the table. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
is_self_referencing	yes_or_no	Applies to a feature not available in PostgreSQL
is_identity	yes_or_no	Applies to a feature not available in PostgreSQL
identity_generation	character_data	Applies to a feature not available in PostgreSQL
identity_start	character_data	Applies to a feature not available in PostgreSQL
identity_increment	character_data	Applies to a feature not available in PostgreSQL
identity_maximum	character_data	Applies to a feature not available in PostgreSQL
identity_minimum	character_data	Applies to a feature not available in PostgreSQL
identity_cycle	yes_or_no	Applies to a feature not available in PostgreSQL
is_generated	character_data	Applies to a feature not available in PostgreSQL
generation_expression	character_data	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
is_updatable	yes_or_no	YES if the column is updatable, NO if not (Columns in base tables are always updatable, columns in views not necessarily)

Since data types can be defined in a variety of ways in SQL, and PostgreSQL contains additional ways to define data types, their representation in the information schema can be somewhat difficult. The column data_type is supposed to identify the underlying built-in type of the column. In PostgreSQL, this means that the type is defined in the system catalog schema pg_catalog. This column might be useful if the application can handle the well-known built-in types specially (for example, format the numeric types differently or use the data in the precision columns). The columns udt_name, udt_schema, and udt_catalog always identify the underlying data type of the column, even if the column is based on a domain. (Since PostgreSQL treats built-in types like user-defined types, built-in types appear here as well. This is an extension of the SQL standard.) These columns should be used if an application wants to process data differently according to the type, because in that case it wouldn't matter if the column is really based on a domain. If the column is based on a domain, the identity of the domain is stored in the columns domain_name, domain_schema, and domain_catalog. If you want to pair up columns with their associated data types and treat domains as separate types, you could write coalesce(domain_name, udt_name), etc.

34.17. constraint_column_usage

The view constraint_column_usage identifies all columns in the current database that are used by some constraint. Only those columns are shown that are contained in a table owned by a currently enabled role. For a check constraint, this view identifies the columns that are used in the check expression. For a foreign key constraint, this view identifies the columns that the foreign key references. For a unique or primary key constraint, this view identifies the constrained columns.

Table 34-15. constraint_column_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the table that contains the column that is used by some constraint (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column that is used by some constraint
table_name	sql_identifier	Name of the table that contains the column that is used by some constraint
column_name	sql_identifier	Name of the column that is used by some constraint

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint

34.18. constraint_table_usage

The view constraint_table_usage identifies all tables in the current database that are used by some constraint and are owned by a currently enabled role. (This is different from the view table_constraints, which identifies all table constraints along with the table they are defined on.) For a foreign key constraint, this view identifies the table that the foreign key references. For a unique or primary key constraint, this view simply identifies the table the constraint belongs to. Check constraints and not-null constraints are not included in this view.

Table 34-16. constraint_table_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the table that is used by some constraint (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that is used by some constraint
table_name	sql_identifier	Name of the table that is used by some constraint
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint

34.19. data_type_privileges

The view data_type_privileges identifies all data type descriptors that the current user has access to, by way of being the owner of the described object or having some privilege for it. A data type descriptor is generated whenever a data type is used in the definition of a table column, a domain, or a function (as parameter or return type) and stores some information about how the data type is used in that instance (for example, the declared maximum length, if applicable). Each data type descriptor is assigned an arbitrary identifier that is unique among the data type descriptor identifiers assigned for one object (table, domain, function). This view is probably not useful for applications, but it is used to define some other views in the information schema.

Table 34-17. `data_type_privileges` Columns

Name	Data Type	Description
`object_catalog`	`sql_identifier`	Name of the database that contains the described object (always the current database)
`object_schema`	`sql_identifier`	Name of the schema that contains the described object
`object_name`	`sql_identifier`	Name of the described object
`object_type`	`character_data`	The type of the described object: one of `TABLE` (the data type descriptor pertains to a column of that table), `DOMAIN` (the data type descriptors pertains to that domain), `ROUTINE` (the data type descriptor pertains to a parameter or the return data type of that function).
`dtd_identifier`	`sql_identifier`	The identifier of the data type descriptor, which is unique among the data type descriptors for that same object.

34.20. `domain_constraints`

The view `domain_constraints` contains all constraints belonging to domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-18. `domain_constraints` Columns

Name	Data Type	Description
`constraint_catalog`	`sql_identifier`	Name of the database that contains the constraint (always the current database)
`constraint_schema`	`sql_identifier`	Name of the schema that contains the constraint
`constraint_name`	`sql_identifier`	Name of the constraint
`domain_catalog`	`sql_identifier`	Name of the database that contains the domain (always the current database)
`domain_schema`	`sql_identifier`	Name of the schema that contains the domain
`domain_name`	`sql_identifier`	Name of the domain
`is_deferrable`	`yes_or_no`	`YES` if the constraint is deferrable, `NO` if not

Name	Data Type	Description
initially_deferred	yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not

34.21. domain_udt_usage

The view domain_udt_usage identifies all domains that are based on data types owned by a currently enabled role. Note that in PostgreSQL, built-in data types behave like user-defined types, so they are included here as well.

Table 34-19. domain_udt_usage Columns

Name	Data Type	Description
udt_catalog	sql_identifier	Name of the database that the domain data type is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the domain data type is defined in
udt_name	sql_identifier	Name of the domain data type
domain_catalog	sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema	sql_identifier	Name of the schema that contains the domain
domain_name	sql_identifier	Name of the domain

34.22. domains

The view domains contains all domains defined in the current database. Only those domains are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-20. domains Columns

Name	Data Type	Description
domain_catalog	sql_identifier	Name of the database that contains the domain (always the current database)
domain_schema	sql_identifier	Name of the schema that contains the domain
domain_name	sql_identifier	Name of the domain

Name	Data Type	Description
data_type	character_data	Data type of the domain, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in udt_name and associated columns).
character_maximum_length	cardinal_number	If the domain has a character or bit string type, the declared maximum length; null for all other data types or if no maximum length was declared.
character_octet_length	cardinal_number	If the domain has a character type, the maximum possible length in octets (bytes) of a datum; null for all other data types. The maximum octet length depends on the declared character maximum length (see above) and the server encoding.
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the domain (always the current database), null if default or the data type of the domain is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the domain, null if default or the data type of the domain is not collatable
collation_name	sql_identifier	Name of the collation of the domain, null if default or the data type of the domain is not collatable

Name	Data Type	Description
numeric_precision	cardinal_number	If the domain has a numeric type, this column contains the (declared or implicit) precision of the type for this domain. The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
numeric_precision_radix	cardinal_number	If the domain has a numeric type, this column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10. For all other data types, this column is null.
numeric_scale	cardinal_number	If the domain has an exact numeric type, this column contains the (declared or implicit) scale of the type for this domain. The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix. For all other data types, this column is null.
datetime_precision	cardinal_number	If data_type identifies a date, time, timestamp, or interval type, this column contains the (declared or implicit) fractional seconds precision of the type for this domain, that is, the number of decimal digits maintained following the decimal point in the seconds value. For all other data types, this column is null.

Name	Data Type	Description
interval_type	character_data	If data_type identifies an interval type, this column contains the specification which fields the intervals include for this domain, e.g., YEAR TO MONTH, DAY TO SECOND, etc. If no field restrictions were specified (that is, the interval accepts all fields), and for all other data types, this field is null.
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL (see datetime_precision for the fractional seconds precision of interval type domains)
domain_default	character_data	Default expression of the domain
udt_catalog	sql_identifier	Name of the database that the domain data type is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the domain data type is defined in
udt_name	sql_identifier	Name of the domain data type
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the domain, unique among the data type descriptors pertaining to the domain (which is trivial, because a domain only contains one data type descriptor). This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)

34.23. element_types

The view element_types contains the data type descriptors of the elements of arrays. When a table column, composite-type attribute, domain, function parameter, or function return value is defined to be of an array type, the respective information schema view only contains ARRAY in the column data_type. To obtain information on the element type of the array, you can join the respective view with this view. For example, to show the columns of a table with data types and array element types, if applicable, you could do:

```
SELECT c.column_name, c.data_type, e.data_type AS element_type
FROM information_schema.columns c LEFT JOIN information_schema.element_types e
     ON ((c.table_catalog, c.table_schema, c.table_name, 'TABLE', c.dtd_identifier)
       = (e.object_catalog, e.object_schema, e.object_name, e.object_type, e.collection_
WHERE c.table_schema = '...' AND c.table_name = '...'
ORDER BY c.ordinal_position;
```

This view only includes objects that the current user has access to, by way of being the owner or having some privilege.

Table 34-21. element_types Columns

Name	Data Type	Description
object_catalog	sql_identifier	Name of the database that contains the object that uses the array being described (always the current database)
object_schema	sql_identifier	Name of the schema that contains the object that uses the array being described
object_name	sql_identifier	Name of the object that uses the array being described
object_type	character_data	The type of the object that uses the array being described: one of TABLE (the array is used by a column of that table), USER-DEFINED TYPE (the array is used by an attribute of that composite type), DOMAIN (the array is used by that domain), ROUTINE (the array is used by a parameter or the return data type of that function).
collection_type_identifier	sql_identifier	The identifier of the data type descriptor of the array being described. Use this to join with the dtd_identifier columns of other information schema views.

Name	Data Type	Description
data_type	character_data	Data type of the array elements, if it is a built-in type, else USER-DEFINED (in that case, the type is identified in udt_name and associated columns).
character_maximum_length	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
character_octet_length	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Name of the database containing the collation of the element type (always the current database), null if default or the data type of the element is not collatable
collation_schema	sql_identifier	Name of the schema containing the collation of the element type, null if default or the data type of the element is not collatable
collation_name	sql_identifier	Name of the collation of the element type, null if default or the data type of the element is not collatable
numeric_precision	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
numeric_precision_radix	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
numeric_scale	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL

Name	Data Type	Description
datetime_precision	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
interval_type	character_data	Always null, since this information is not applied to array element data types in PostgreSQL
interval_precision	cardinal_number	Always null, since this information is not applied to array element data types in PostgreSQL
domain_default	character_data	Not yet implemented
udt_catalog	sql_identifier	Name of the database that the data type of the elements is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the data type of the elements is defined in
udt_name	sql_identifier	Name of the data type of the elements
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the element. This is currently not useful.

34.24. enabled_roles

The view enabled_roles identifies the currently "enabled roles". The enabled roles are recursively defined as the current user together with all roles that have been granted to the enabled roles with automatic inheritance. In other words, these are all roles that the current user has direct or indirect, automatically inheriting membership in.

For permission checking, the set of "applicable roles" is applied, which can be broader than the set of enabled roles. So generally, it is better to use the view applicable_roles instead of this one; see also there.

Table 34-22. `enabled_roles` Columns

Name	Data Type	Description
`role_name`	`sql_identifier`	Name of a role

34.25. `foreign_data_wrapper_options`

The view `foreign_data_wrapper_options` contains all the options defined for foreign-data wrappers in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-23. `foreign_data_wrapper_options` Columns

Name	Data Type	Description
`foreign_data_wrapper_catalog`	`sql_identifier`	Name of the database that the foreign-data wrapper is defined in (always the current database)
`foreign_data_wrapper_name`	`sql_identifier`	Name of the foreign-data wrapper
`option_name`	`sql_identifier`	Name of an option
`option_value`	`character_data`	Value of the option

34.26. `foreign_data_wrappers`

The view `foreign_data_wrappers` contains all foreign-data wrappers defined in the current database. Only those foreign-data wrappers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-24. `foreign_data_wrappers` Columns

Name	Data Type	Description
`foreign_data_wrapper_catalog`	`sql_identifier`	Name of the database that contains the foreign-data wrapper (always the current database)
`foreign_data_wrapper_name`	`sql_identifier`	Name of the foreign-data wrapper
`authorization_identifier`	`sql_identifier`	Name of the owner of the foreign server
`library_name`	`character_data`	File name of the library that implementing this foreign-data wrapper
`foreign_data_wrapper_language`	`character_data`	Language used to implement this foreign-data wrapper

34.27. foreign_server_options

The view foreign_server_options contains all the options defined for foreign servers in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-25. foreign_server_options Columns

Name	Data Type	Description
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

34.28. foreign_servers

The view foreign_servers contains all foreign servers defined in the current database. Only those foreign servers are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-26. foreign_servers Columns

Name	Data Type	Description
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server
foreign_data_wrapper_catalog	sql_identifier	Name of the database that contains the foreign-data wrapper used by the foreign server (always the current database)
foreign_data_wrapper_name	sql_identifier	Name of the foreign-data wrapper used by the foreign server
foreign_server_type	character_data	Foreign server type information, if specified upon creation
foreign_server_version	character_data	Foreign server version information, if specified upon creation
authorization_identifier	sql_identifier	Name of the owner of the foreign server

34.29. foreign_table_options

The view foreign_table_options contains all the options defined for foreign tables in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-27. foreign_table_options Columns

Name	Data Type	Description
foreign_table_catalog	sql_identifier	Name of the database that contains the foreign table (always the current database)
foreign_table_schema	sql_identifier	Name of the schema that contains the foreign table
foreign_table_name	sql_identifier	Name of the foreign table
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server
option_name	sql_identifier	Name of an option
option_value	character_data	Value of the option

34.30. foreign_tables

The view foreign_tables contains all foreign tables defined in the current database. Only those foreign tables are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-28. foreign_tables Columns

Name	Data Type	Description
foreign_table_catalog	sql_identifier	Name of the database that the foreign table is defined in (always the current database)
foreign_table_schema	sql_identifier	Name of the schema that contains the foreign table
foreign_table_name	sql_identifier	Name of the foreign table
foreign_server_catalog	sql_identifier	Name of the database that the foreign server is defined in (always the current database)
foreign_server_name	sql_identifier	Name of the foreign server

34.31. key_column_usage

The view key_column_usage identifies all columns in the current database that are restricted by

some unique, primary key, or foreign key constraint. Check constraints are not included in this view. Only those columns are shown that the current user has access to, by way of being the owner or having some privilege.

Table 34-29. `key_column_usage` Columns

Name	Data Type	Description
`constraint_catalog`	`sql_identifier`	Name of the database that contains the constraint (always the current database)
`constraint_schema`	`sql_identifier`	Name of the schema that contains the constraint
`constraint_name`	`sql_identifier`	Name of the constraint
`table_catalog`	`sql_identifier`	Name of the database that contains the table that contains the column that is restricted by this constraint (always the current database)
`table_schema`	`sql_identifier`	Name of the schema that contains the table that contains the column that is restricted by this constraint
`table_name`	`sql_identifier`	Name of the table that contains the column that is restricted by this constraint
`column_name`	`sql_identifier`	Name of the column that is restricted by this constraint
`ordinal_position`	`cardinal_number`	Ordinal position of the column within the constraint key (count starts at 1)
`position_in_unique_constraint`	`cardinal_number`	For a foreign-key constraint, ordinal position of the referenced column within its unique constraint (count starts at 1); otherwise null

34.32. `parameters`

The view `parameters` contains information about the parameters (arguments) of all functions in the current database. Only those functions are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-30. `parameters` Columns

Name	Data Type	Description

Name	Data Type	Description
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The "specific name" of the function. See Section 34.40 for more information.
ordinal_position	cardinal_number	Ordinal position of the parameter in the argument list of the function (count starts at 1)
parameter_mode	character_data	IN for input parameter, OUT for output parameter, and INOUT for input/output parameter.
is_result	yes_or_no	Applies to a feature not available in PostgreSQL
as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
parameter_name	sql_identifier	Name of the parameter, or null if the parameter has no name
data_type	character_data	Data type of the parameter, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in udt_name and associated columns).
character_maximum_length	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
character_octet_length	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL

Name	Data Type	Description
collation_schema	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL
collation_name	sql_identifier	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_precision_radix	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
numeric_scale	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
datetime_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
interval_type	character_data	Always null, since this information is not applied to parameter data types in PostgreSQL
interval_precision	cardinal_number	Always null, since this information is not applied to parameter data types in PostgreSQL
udt_catalog	sql_identifier	Name of the database that the data type of the parameter is defined in (always the current database)
udt_schema	sql_identifier	Name of the schema that the data type of the parameter is defined in
udt_name	sql_identifier	Name of the data type of the parameter
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the parameter, unique among the data type descriptors pertaining to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
parameter_default	character_data	The default expression of the parameter, or null if none or if the function is not owned by a currently enabled role.

34.33. referential_constraints

The view referential_constraints contains all referential (foreign key) constraints in the current database. Only those constraints are shown for which the current user has write access to the referencing table (by way of being the owner or having some privilege other than SELECT).

Table 34-31. referential_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database containing the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema containing the constraint
constraint_name	sql_identifier	Name of the constraint
unique_constraint_catalog	sql_identifier	Name of the database that contains the unique or primary key constraint that the foreign key constraint references (always the current database)
unique_constraint_schema	sql_identifier	Name of the schema that contains the unique or primary key constraint that the foreign key constraint references

Name	Data Type	Description
unique_constraint_name	sql_identifier	Name of the unique or primary key constraint that the foreign key constraint references
match_option	character_data	Match option of the foreign key constraint: FULL, PARTIAL, or NONE.
update_rule	character_data	Update rule of the foreign key constraint: CASCADE, SET NULL, SET DEFAULT, RESTRICT, or NO ACTION.
delete_rule	character_data	Delete rule of the foreign key constraint: CASCADE, SET NULL, SET DEFAULT, RESTRICT, or NO ACTION.

34.34. role_column_grants

The view role_column_grants identifies all privileges granted on columns where the grantor or grantee is a currently enabled role. Further information can be found under column_privileges. The only effective difference between this view and column_privileges is that this view omits columns that have been made accessible to the current user by way of a grant to PUBLIC.

Table 34-32. role_column_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table that contains the column (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column
table_name	sql_identifier	Name of the table that contains the column
column_name	sql_identifier	Name of the column
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, or REFERENCES
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.35. role_routine_grants

The view role_routine_grants identifies all privileges granted on functions where the grantor or grantee is a currently enabled role. Further information can be found under routine_privileges. The only effective difference between this view and routine_privileges is that this view omits functions that have been made accessible to the current user by way of a grant to PUBLIC.

Table 34-33. role_routine_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The "specific name" of the function. See Section 34.40 for more information.
routine_catalog	sql_identifier	Name of the database containing the function (always the current database)
routine_schema	sql_identifier	Name of the schema containing the function
routine_name	sql_identifier	Name of the function (might be duplicated in case of overloading)
privilege_type	character_data	Always EXECUTE (the only privilege type for functions)
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.36. role_table_grants

The view role_table_grants identifies all privileges granted on tables or views where the grantor or grantee is a currently enabled role. Further information can be found under table_privileges. The only effective difference between this view and table_privileges is that this view omits tables that have been made accessible to the current user by way of a grant to PUBLIC.

Table 34-34. role_table_grants Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege

Name	Data Type	Description
grantee	sql_identifier	Name of the role that the privilege was granted to
table_catalog	sql_identifier	Name of the database that contains the table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table
table_name	sql_identifier	Name of the table
privilege_type	character_data	Type of the privilege: SELECT, INSERT, UPDATE, DELETE, TRUNCATE, REFERENCES, or TRIGGER
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not
with_hierarchy	yes_or_no	In the SQL standard, WITH HIERARCHY OPTION is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In PostgreSQL, this is included in the SELECT privilege, so this column shows YES if the privilege is SELECT, else NO.

34.37. role_udt_grants

The view role_udt_grants is intended to identify USAGE privileges granted on user-defined types where the grantor or grantee is a currently enabled role. Further information can be found under udt_privileges. The only effective difference between this view and udt_privileges is that this view omits objects that have been made accessible to the current user by way of a grant to PUBLIC. Since data types do not have real privileges in PostgreSQL, but only an implicit grant to PUBLIC, this view is empty.

Table 34-35. role_udt_grants Columns

Name	Data Type	Description
grantor	sql_identifier	The name of the role that granted the privilege
grantee	sql_identifier	The name of the role that the privilege was granted to
udt_catalog	sql_identifier	Name of the database containing the type (always the current database)
udt_schema	sql_identifier	Name of the schema containing the type
udt_name	sql_identifier	Name of the type

Name	Data Type	Description
privilege_type	character_data	Always TYPE USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.38. role_usage_grants

The view role_usage_grants identifies USAGE privileges granted on various kinds of objects where the grantor or grantee is a currently enabled role. Further information can be found under usage_privileges. The only effective difference between this view and usage_privileges is that this view omits objects that have been made accessible to the current user by way of a grant to PUBLIC.

Table 34-36. role_usage_grants Columns

Name	Data Type	Description
grantor	sql_identifier	The name of the role that granted the privilege
grantee	sql_identifier	The name of the role that the privilege was granted to
object_catalog	sql_identifier	Name of the database containing the object (always the current database)
object_schema	sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name	sql_identifier	Name of the object
object_type	character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type	character_data	Always USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.39. routine_privileges

The view routine_privileges identifies all privileges granted on functions to a currently enabled role or by a currently enabled role. There is one row for each combination of function, grantor, and grantee.

Table 34-37. routine_privileges Columns

Name	Data Type	Description

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The "specific name" of the function. See Section 34.40 for more information.
routine_catalog	sql_identifier	Name of the database containing the function (always the current database)
routine_schema	sql_identifier	Name of the schema containing the function
routine_name	sql_identifier	Name of the function (might be duplicated in case of overloading)
privilege_type	character_data	Always EXECUTE (the only privilege type for functions)
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.40. routines

The view routines contains all functions in the current database. Only those functions are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-38. routines Columns

Name	Data Type	Description
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function

Name	Data Type	Description
specific_name	sql_identifier	The "specific name" of the function. This is a name that uniquely identifies the function in the schema, even if the real name of the function is overloaded. The format of the specific name is not defined, it should only be used to compare it to other instances of specific routine names.
routine_catalog	sql_identifier	Name of the database containing the function (always the current database)
routine_schema	sql_identifier	Name of the schema containing the function
routine_name	sql_identifier	Name of the function (might be duplicated in case of overloading)
routine_type	character_data	Always FUNCTION (In the future there might be other types of routines.)
module_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
module_schema	sql_identifier	Applies to a feature not available in PostgreSQL
module_name	sql_identifier	Applies to a feature not available in PostgreSQL
udt_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
udt_schema	sql_identifier	Applies to a feature not available in PostgreSQL
udt_name	sql_identifier	Applies to a feature not available in PostgreSQL
data_type	character_data	Return data type of the function, if it is a built-in type, or ARRAY if it is some array (in that case, see the view element_types), else USER-DEFINED (in that case, the type is identified in type_udt_name and associated columns).
character_maximum_length	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL

Name	Data Type	Description
character_octet_length	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
collation_schema	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
collation_name	sql_identifier	Always null, since this information is not applied to return data types in PostgreSQL
numeric_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
numeric_precision_radix	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
numeric_scale	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
datetime_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL
interval_type	character_data	Always null, since this information is not applied to return data types in PostgreSQL
interval_precision	cardinal_number	Always null, since this information is not applied to return data types in PostgreSQL

Name	Data Type	Description
type_udt_catalog	sql_identifier	Name of the database that the return data type of the function is defined in (always the current database)
type_udt_schema	sql_identifier	Name of the schema that the return data type of the function is defined in
type_udt_name	sql_identifier	Name of the return data type of the function
scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
maximum_cardinality	cardinal_number	Always null, because arrays always have unlimited maximum cardinality in PostgreSQL
dtd_identifier	sql_identifier	An identifier of the data type descriptor of the return data type of this function, unique among the data type descriptors pertaining to the function. This is mainly useful for joining with other instances of such identifiers. (The specific format of the identifier is not defined and not guaranteed to remain the same in future versions.)
routine_body	character_data	If the function is an SQL function, then SQL, else EXTERNAL.
routine_definition	character_data	The source text of the function (null if the function is not owned by a currently enabled role). (According to the SQL standard, this column is only applicable if routine_body is SQL, but in PostgreSQL it will contain whatever source text was specified when the function was created.)

Name	Data Type	Description
external_name	character_data	If this function is a C function, then the external name (link symbol) of the function; else null. (This works out to be the same value that is shown in routine_definition.)
external_language	character_data	The language the function is written in
parameter_style	character_data	Always GENERAL (The SQL standard defines other parameter styles, which are not available in PostgreSQL.)
is_deterministic	yes_or_no	If the function is declared immutable (called deterministic in the SQL standard), then YES, else NO. (You cannot query the other volatility levels available in PostgreSQL through the information schema.)
sql_data_access	character_data	Always MODIFIES, meaning that the function possibly modifies SQL data. This information is not useful for PostgreSQL.
is_null_call	yes_or_no	If the function automatically returns null if any of its arguments are null, then YES, else NO.
sql_path	character_data	Applies to a feature not available in PostgreSQL
schema_level_routine	yes_or_no	Always YES (The opposite would be a method of a user-defined type, which is a feature not available in PostgreSQL.)
max_dynamic_result_sets	cardinal_number	Applies to a feature not available in PostgreSQL
is_user_defined_cast	yes_or_no	Applies to a feature not available in PostgreSQL
is_implicitly_invocable	yes_or_no	Applies to a feature not available in PostgreSQL
security_type	character_data	If the function runs with the privileges of the current user, then INVOKER, if the function runs with the privileges of the user who defined it, then DEFINER.

Name	Data Type	Description
to_sql_specific_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
to_sql_specific_schema	sql_identifier	Applies to a feature not available in PostgreSQL
to_sql_specific_name	sql_identifier	Applies to a feature not available in PostgreSQL
as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
created	time_stamp	Applies to a feature not available in PostgreSQL
last_altered	time_stamp	Applies to a feature not available in PostgreSQL
new_savepoint_level	yes_or_no	Applies to a feature not available in PostgreSQL
is_udt_dependent	yes_or_no	Currently always NO. The alternative YES applies to a feature not available in PostgreSQL.
result_cast_from_data_type	character_data	Applies to a feature not available in PostgreSQL
result_cast_as_locator	yes_or_no	Applies to a feature not available in PostgreSQL
result_cast_char_max_length	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_char_octet_length	character_data	Applies to a feature not available in PostgreSQL
result_cast_char_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_char_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_char_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_collation_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_collation_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_collation_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_numeric_precision	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_numeric_precision_radix	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_numeric_scale	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_datetime_precision	character_data	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
result_cast_interval_type	character_data	Applies to a feature not available in PostgreSQL
result_cast_interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_type_udt_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_type_udt_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_type_udt_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_schema	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_scope_name	sql_identifier	Applies to a feature not available in PostgreSQL
result_cast_maximum_cardinality	cardinal_number	Applies to a feature not available in PostgreSQL
result_cast_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL

34.41. schemata

The view schemata contains all schemas in the current database that the current user has access to (by way of being the owner or having some privilege).

Table 34-39. schemata Columns

Name	Data Type	Description
catalog_name	sql_identifier	Name of the database that the schema is contained in (always the current database)
schema_name	sql_identifier	Name of the schema
schema_owner	sql_identifier	Name of the owner of the schema
default_character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
default_character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
default_character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
sql_path	character_data	Applies to a feature not available in PostgreSQL

34.42. sequences

The view sequences contains all sequences defined in the current database. Only those sequences are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-40. sequences Columns

Name	Data Type	Description
sequence_catalog	sql_identifier	Name of the database that contains the sequence (always the current database)
sequence_schema	sql_identifier	Name of the schema that contains the sequence
sequence_name	sql_identifier	Name of the sequence
data_type	character_data	The data type of the sequence. In PostgreSQL, this is currently always bigint.
numeric_precision	cardinal_number	This column contains the (declared or implicit) precision of the sequence data type (see above). The precision indicates the number of significant digits. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix.
numeric_precision_radix	cardinal_number	This column indicates in which base the values in the columns numeric_precision and numeric_scale are expressed. The value is either 2 or 10.
numeric_scale	cardinal_number	This column contains the (declared or implicit) scale of the sequence data type (see above). The scale indicates the number of significant digits to the right of the decimal point. It can be expressed in decimal (base 10) or binary (base 2) terms, as specified in the column numeric_precision_radix.
start_value	character_data	The start value of the sequence
minimum_value	character_data	The minimum value of the sequence

Name	Data Type	Description
maximum_value	character_data	The maximum value of the sequence
increment	character_data	The increment of the sequence
cycle_option	yes_or_no	YES if the sequence cycles, else NO

Note that in accordance with the SQL standard, the start, minimum, maximum, and increment values are returned as character strings.

34.43. sql_features

The table sql_features contains information about which formal features defined in the SQL standard are supported by PostgreSQL. This is the same information that is presented in Appendix D. There you can also find some additional background information.

Table 34-41. sql_features Columns

Name	Data Type	Description
feature_id	character_data	Identifier string of the feature
feature_name	character_data	Descriptive name of the feature
sub_feature_id	character_data	Identifier string of the subfeature, or a zero-length string if not a subfeature
sub_feature_name	character_data	Descriptive name of the subfeature, or a zero-length string if not a subfeature
is_supported	yes_or_no	YES if the feature is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the feature

34.44. sql_implementation_info

The table sql_implementation_info contains information about various aspects that are left implementation-defined by the SQL standard. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual implementation information items are not described here; you will find them in the description of the ODBC interface.

Table 34-42. `sql_implementation_info` Columns

Name	Data Type	Description
`implementation_info_id`	`character_data`	Identifier string of the implementation information item
`implementation_info_name`	`character_data`	Descriptive name of the implementation information item
`integer_value`	`cardinal_number`	Value of the implementation information item, or null if the value is contained in the column `character_value`
`character_value`	`character_data`	Value of the implementation information item, or null if the value is contained in the column `integer_value`
`comments`	`character_data`	Possibly a comment pertaining to the implementation information item

34.45. `sql_languages`

The table `sql_languages` contains one row for each SQL language binding that is supported by PostgreSQL. PostgreSQL supports direct SQL and embedded SQL in C; that is all you will learn from this table.

This table was removed from the SQL standard in SQL:2008, so there are no entries referring to standards later than SQL:2003.

Table 34-43. `sql_languages` Columns

Name	Data Type	Description
`sql_language_source`	`character_data`	The name of the source of the language definition; always `ISO 9075`, that is, the SQL standard
`sql_language_year`	`character_data`	The year the standard referenced in `sql_language_source` was approved.
`sql_language_conformance`	`character_data`	The standard conformance level for the language binding. For ISO 9075:2003 this is always `CORE`.
`sql_language_integrity`	`character_data`	Always null (This value is relevant to an earlier version of the SQL standard.)

Name	Data Type	Description
sql_language_implementation	character_data	Always null
sql_language_binding_style	character_data	The language binding style, either DIRECT or EMBEDDED
sql_language_programming_language	character_data	The programming language, if the binding style is EMBEDDED, else null. PostgreSQL only supports the language C.

34.46. sql_packages

The table sql_packages contains information about which feature packages defined in the SQL standard are supported by PostgreSQL. Refer to Appendix D for background information on feature packages.

Table 34-44. sql_packages Columns

Name	Data Type	Description
feature_id	character_data	Identifier string of the package
feature_name	character_data	Descriptive name of the package
is_supported	yes_or_no	YES if the package is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the package

34.47. sql_parts

The table sql_parts contains information about which of the several parts of the SQL standard are supported by PostgreSQL.

Table 34-45. sql_parts Columns

Name	Data Type	Description
feature_id	character_data	An identifier string containing the number of the part
feature_name	character_data	Descriptive name of the part

Name	Data Type	Description
is_supported	yes_or_no	YES if the part is fully supported by the current version of PostgreSQL, NO if not
is_verified_by	character_data	Always null, since the PostgreSQL development group does not perform formal testing of feature conformance
comments	character_data	Possibly a comment about the supported status of the part

34.48. sql_sizing

The table sql_sizing contains information about various size limits and maximum values in PostgreSQL. This information is primarily intended for use in the context of the ODBC interface; users of other interfaces will probably find this information to be of little use. For this reason, the individual sizing items are not described here; you will find them in the description of the ODBC interface.

Table 34-46. sql_sizing Columns

Name	Data Type	Description
sizing_id	cardinal_number	Identifier of the sizing item
sizing_name	character_data	Descriptive name of the sizing item
supported_value	cardinal_number	Value of the sizing item, or 0 if the size is unlimited or cannot be determined, or null if the features for which the sizing item is applicable are not supported
comments	character_data	Possibly a comment pertaining to the sizing item

34.49. sql_sizing_profiles

The table sql_sizing_profiles contains information about the sql_sizing values that are required by various profiles of the SQL standard. PostgreSQL does not track any SQL profiles, so this table is empty.

Table 34-47. sql_sizing_profiles Columns

Name	Data Type	Description
sizing_id	cardinal_number	Identifier of the sizing item
sizing_name	character_data	Descriptive name of the sizing item

Name	Data Type	Description
profile_id	character_data	Identifier string of a profile
required_value	cardinal_number	The value required by the SQL profile for the sizing item, or 0 if the profile places no limit on the sizing item, or null if the profile does not require any of the features for which the sizing item is applicable
comments	character_data	Possibly a comment pertaining to the sizing item within the profile

34.50. table_constraints

The view table_constraints contains all constraints belonging to tables that the current user owns or has some privilege other than SELECT on.

Table 34-48. table_constraints Columns

Name	Data Type	Description
constraint_catalog	sql_identifier	Name of the database that contains the constraint (always the current database)
constraint_schema	sql_identifier	Name of the schema that contains the constraint
constraint_name	sql_identifier	Name of the constraint
table_catalog	sql_identifier	Name of the database that contains the table (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table
table_name	sql_identifier	Name of the table
constraint_type	character_data	Type of the constraint: CHECK, FOREIGN KEY, PRIMARY KEY, or UNIQUE
is_deferrable	yes_or_no	YES if the constraint is deferrable, NO if not
initially_deferred	yes_or_no	YES if the constraint is deferrable and initially deferred, NO if not

34.51. table_privileges

The view table_privileges identifies all privileges granted on tables or views to a currently en-

abled role or by a currently enabled role. There is one row for each combination of table, grantor, and grantee.

Table 34-49. `table_privileges` Columns

Name	Data Type	Description
`grantor`	`sql_identifier`	Name of the role that granted the privilege
`grantee`	`sql_identifier`	Name of the role that the privilege was granted to
`table_catalog`	`sql_identifier`	Name of the database that contains the table (always the current database)
`table_schema`	`sql_identifier`	Name of the schema that contains the table
`table_name`	`sql_identifier`	Name of the table
`privilege_type`	`character_data`	Type of the privilege: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, `REFERENCES`, or `TRIGGER`
`is_grantable`	`yes_or_no`	`YES` if the privilege is grantable, `NO` if not
`with_hierarchy`	`yes_or_no`	In the SQL standard, `WITH HIERARCHY OPTION` is a separate (sub-)privilege allowing certain operations on table inheritance hierarchies. In PostgreSQL, this is included in the `SELECT` privilege, so this column shows `YES` if the privilege is `SELECT`, else `NO`.

34.52. `tables`

The view `tables` contains all tables and views defined in the current database. Only those tables and views are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-50. `tables` Columns

Name	Data Type	Description
`table_catalog`	`sql_identifier`	Name of the database that contains the table (always the current database)
`table_schema`	`sql_identifier`	Name of the schema that contains the table
`table_name`	`sql_identifier`	Name of the table

Name	Data Type	Description
table_type	character_data	Type of the table: BASE TABLE for a persistent base table (the normal table type), VIEW for a view, FOREIGN TABLE for a foreign table, or LOCAL TEMPORARY for a temporary table
self_referencing_column_name	sql_identifier	Applies to a feature not available in PostgreSQL
reference_generation	character_data	Applies to a feature not available in PostgreSQL
user_defined_type_catalog	sql_identifier	If the table is a typed table, the name of the database that contains the underlying data type (always the current database), else null.
user_defined_type_schema	sql_identifier	If the table is a typed table, the name of the schema that contains the underlying data type, else null.
user_defined_type_name	sql_identifier	If the table is a typed table, the name of the underlying data type, else null.
is_insertable_into	yes_or_no	YES if the table is insertable into, NO if not (Base tables are always insertable into, views not necessarily.)
is_typed	yes_or_no	YES if the table is a typed table, NO if not
commit_action	character_data	Not yet implemented

34.53. triggered_update_columns

For triggers in the current database that specify a column list (like UPDATE OF column1, column2), the view triggered_update_columns identifies these columns. Triggers that do not specify a column list are not included in this view. Only those columns are shown that the current user owns or has some privilege other than SELECT on.

Table 34-51. triggered_update_columns Columns

Name	Data Type	Description
trigger_catalog	sql_identifier	Name of the database that contains the trigger (always the current database)
trigger_schema	sql_identifier	Name of the schema that contains the trigger

Name	Data Type	Description
trigger_name	sql_identifier	Name of the trigger
event_object_catalog	sql_identifier	Name of the database that contains the table that the trigger is defined on (always the current database)
event_object_schema	sql_identifier	Name of the schema that contains the table that the trigger is defined on
event_object_table	sql_identifier	Name of the table that the trigger is defined on
event_object_column	sql_identifier	Name of the column that the trigger is defined on

34.54. triggers

The view triggers contains all triggers defined in the current database on tables and views that the current user owns or has some privilege other than SELECT on.

Table 34-52. triggers Columns

Name	Data Type	Description
trigger_catalog	sql_identifier	Name of the database that contains the trigger (always the current database)
trigger_schema	sql_identifier	Name of the schema that contains the trigger
trigger_name	sql_identifier	Name of the trigger
event_manipulation	character_data	Event that fires the trigger (INSERT, UPDATE, or DELETE)
event_object_catalog	sql_identifier	Name of the database that contains the table that the trigger is defined on (always the current database)
event_object_schema	sql_identifier	Name of the schema that contains the table that the trigger is defined on
event_object_table	sql_identifier	Name of the table that the trigger is defined on
action_order	cardinal_number	Not yet implemented
action_condition	character_data	WHEN condition of the trigger, null if none (also null if the table is not owned by a currently enabled role)

Name	Data Type	Description
action_statement	character_data	Statement that is executed by the trigger (currently always EXECUTE PROCEDURE *function*(...))
action_orientation	character_data	Identifies whether the trigger fires once for each processed row or once for each statement (ROW or STATEMENT)
action_timing	character_data	Time at which the trigger fires (BEFORE, AFTER, or INSTEAD OF)
action_reference_old_table	sql_identifier	Applies to a feature not available in PostgreSQL
action_reference_new_table	sql_identifier	Applies to a feature not available in PostgreSQL
action_reference_old_row	sql_identifier	Applies to a feature not available in PostgreSQL
action_reference_new_row	sql_identifier	Applies to a feature not available in PostgreSQL
created	time_stamp	Applies to a feature not available in PostgreSQL

Triggers in PostgreSQL have two incompatibilities with the SQL standard that affect the representation in the information schema. First, trigger names are local to each table in PostgreSQL, rather than being independent schema objects. Therefore there can be duplicate trigger names defined in one schema, so long as they belong to different tables. (trigger_catalog and trigger_schema are really the values pertaining to the table that the trigger is defined on.) Second, triggers can be defined to fire on multiple events in PostgreSQL (e.g., ON INSERT OR UPDATE), whereas the SQL standard only allows one. If a trigger is defined to fire on multiple events, it is represented as multiple rows in the information schema, one for each type of event. As a consequence of these two issues, the primary key of the view triggers is really (trigger_catalog, trigger_schema, event_object_table, trigger_name, event_manipulation) instead of (trigger_catalog, trigger_schema, trigger_name), which is what the SQL standard specifies. Nonetheless, if you define your triggers in a manner that conforms with the SQL standard (trigger names unique in the schema and only one event type per trigger), this will not affect you.

> **Note:** Prior to PostgreSQL 9.1, this view's columns action_timing, action_reference_old_table, action_reference_new_table, action_reference_old_row, and action_reference_new_row were named condition_timing, condition_reference_old_table, condition_reference_new_table, condition_reference_old_row, and condition_reference_new_row respectively. That was how they were named in the SQL:1999 standard. The new naming conforms to SQL:2003 and later.

34.55. udt_privileges

The view udt_privileges identifies USAGE privileges granted on user-defined types to a currently enabled role or by a currently enabled role. There is one row for each combination of column, grantor, and grantee. This view shows only composite types (see under Section 34.57 for why); see Section 34.56 for domain privileges.

Table 34-53. udt_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
udt_catalog	sql_identifier	Name of the database containing the type (always the current database)
udt_schema	sql_identifier	Name of the schema containing the type
udt_name	sql_identifier	Name of the type
privilege_type	character_data	Always TYPE USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.56. usage_privileges

The view usage_privileges identifies USAGE privileges granted on various kinds of objects to a currently enabled role or by a currently enabled role. In PostgreSQL, this currently applies to collations, domains, foreign-data wrappers, foreign servers, and sequences. There is one row for each combination of object, grantor, and grantee.

Since collations do not have real privileges in PostgreSQL, this view shows implicit non-grantable USAGE privileges granted by the owner to PUBLIC for all collations. The other object types, however, show real privileges.

In PostgreSQL, sequences also support SELECT and UPDATE privileges in addition to the USAGE privilege. These are nonstandard and therefore not visible in the information schema.

Table 34-54. usage_privileges Columns

Name	Data Type	Description
grantor	sql_identifier	Name of the role that granted the privilege
grantee	sql_identifier	Name of the role that the privilege was granted to
object_catalog	sql_identifier	Name of the database containing the object (always the current database)

Name	Data Type	Description
object_schema	sql_identifier	Name of the schema containing the object, if applicable, else an empty string
object_name	sql_identifier	Name of the object
object_type	character_data	COLLATION or DOMAIN or FOREIGN DATA WRAPPER or FOREIGN SERVER or SEQUENCE
privilege_type	character_data	Always USAGE
is_grantable	yes_or_no	YES if the privilege is grantable, NO if not

34.57. user_defined_types

The view user_defined_types currently contains all composite types defined in the current database. Only those types are shown that the current user has access to (by way of being the owner or having some privilege).

SQL knows about two kinds of user-defined types: structured types (also known as composite types in PostgreSQL) and distinct types (not implemented in PostgreSQL). To be future-proof, use the column user_defined_type_category to differentiate between these. Other user-defined types such as base types and enums, which are PostgreSQL extensions, are not shown here. For domains, see Section 34.22 instead.

Table 34-55. user_defined_types Columns

Name	Data Type	Description
user_defined_type_catalog	sql_identifier	Name of the database that contains the type (always the current database)
user_defined_type_schema	sql_identifier	Name of the schema that contains the type
user_defined_type_name	sql_identifier	Name of the type
user_defined_type_category	character_data	Currently always STRUCTURED
is_instantiable	yes_or_no	Applies to a feature not available in PostgreSQL
is_final	yes_or_no	Applies to a feature not available in PostgreSQL
ordering_form	character_data	Applies to a feature not available in PostgreSQL
ordering_category	character_data	Applies to a feature not available in PostgreSQL
ordering_routine_catalog	sql_identifier	Applies to a feature not available in PostgreSQL

Name	Data Type	Description
ordering_routine_schema	sql_identifier	Applies to a feature not available in PostgreSQL
ordering_routine_name	sql_identifier	Applies to a feature not available in PostgreSQL
reference_type	character_data	Applies to a feature not available in PostgreSQL
data_type	character_data	Applies to a feature not available in PostgreSQL
character_maximum_length	cardinal_number	Applies to a feature not available in PostgreSQL
character_octet_length	cardinal_number	Applies to a feature not available in PostgreSQL
character_set_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_schema	sql_identifier	Applies to a feature not available in PostgreSQL
character_set_name	sql_identifier	Applies to a feature not available in PostgreSQL
collation_catalog	sql_identifier	Applies to a feature not available in PostgreSQL
collation_schema	sql_identifier	Applies to a feature not available in PostgreSQL
collation_name	sql_identifier	Applies to a feature not available in PostgreSQL
numeric_precision	cardinal_number	Applies to a feature not available in PostgreSQL
numeric_precision_radix	cardinal_number	Applies to a feature not available in PostgreSQL
numeric_scale	cardinal_number	Applies to a feature not available in PostgreSQL
datetime_precision	cardinal_number	Applies to a feature not available in PostgreSQL
interval_type	character_data	Applies to a feature not available in PostgreSQL
interval_precision	cardinal_number	Applies to a feature not available in PostgreSQL
source_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL
ref_dtd_identifier	sql_identifier	Applies to a feature not available in PostgreSQL

34.58. user_mapping_options

The view user_mapping_options contains all the options defined for user mappings in the current

database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

Table 34-56. `user_mapping_options` Columns

Name	Data Type	Description
`authorization_identifier`	`sql_identifier`	Name of the user being mapped, or `PUBLIC` if the mapping is public
`foreign_server_catalog`	`sql_identifier`	Name of the database that the foreign server used by this mapping is defined in (always the current database)
`foreign_server_name`	`sql_identifier`	Name of the foreign server used by this mapping
`option_name`	`sql_identifier`	Name of an option
`option_value`	`character_data`	Value of the option. This column will show as null unless the current user is the user being mapped, or the mapping is for `PUBLIC` and the current user is the server owner, or the current user is a superuser. The intent is to protect password information stored as user mapping option.

34.59. `user_mappings`

The view `user_mappings` contains all user mappings defined in the current database. Only those user mappings are shown where the current user has access to the corresponding foreign server (by way of being the owner or having some privilege).

Table 34-57. `user_mappings` Columns

Name	Data Type	Description
`authorization_identifier`	`sql_identifier`	Name of the user being mapped, or `PUBLIC` if the mapping is public
`foreign_server_catalog`	`sql_identifier`	Name of the database that the foreign server used by this mapping is defined in (always the current database)
`foreign_server_name`	`sql_identifier`	Name of the foreign server used by this mapping

34.60. view_column_usage

The view view_column_usage identifies all columns that are used in the query expression of a view (the SELECT statement that defines the view). A column is only included if the table that contains the column is owned by a currently enabled role.

Note: Columns of system tables are not included. This should be fixed sometime.

Table 34-58. view_column_usage Columns

Name	Data Type	Description
view_catalog	sql_identifier	Name of the database that contains the view (always the current database)
view_schema	sql_identifier	Name of the schema that contains the view
view_name	sql_identifier	Name of the view
table_catalog	sql_identifier	Name of the database that contains the table that contains the column that is used by the view (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that contains the column that is used by the view
table_name	sql_identifier	Name of the table that contains the column that is used by the view
column_name	sql_identifier	Name of the column that is used by the view

34.61. view_routine_usage

The view view_routine_usage identifies all routines (functions and procedures) that are used in the query expression of a view (the SELECT statement that defines the view). A routine is only included if that routine is owned by a currently enabled role.

Table 34-59. view_routine_usage Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database containing the view (always the current database)
table_schema	sql_identifier	Name of the schema containing the view

Name	Data Type	Description
table_name	sql_identifier	Name of the view
specific_catalog	sql_identifier	Name of the database containing the function (always the current database)
specific_schema	sql_identifier	Name of the schema containing the function
specific_name	sql_identifier	The "specific name" of the function. See Section 34.40 for more information.

34.62. view_table_usage

The view view_table_usage identifies all tables that are used in the query expression of a view (the SELECT statement that defines the view). A table is only included if that table is owned by a currently enabled role.

Note: System tables are not included. This should be fixed sometime.

Table 34-60. view_table_usage Columns

Name	Data Type	Description
view_catalog	sql_identifier	Name of the database that contains the view (always the current database)
view_schema	sql_identifier	Name of the schema that contains the view
view_name	sql_identifier	Name of the view
table_catalog	sql_identifier	Name of the database that contains the table that is used by the view (always the current database)
table_schema	sql_identifier	Name of the schema that contains the table that is used by the view
table_name	sql_identifier	Name of the table that is used by the view

34.63. views

The view views contains all views defined in the current database. Only those views are shown that the current user has access to (by way of being the owner or having some privilege).

Table 34-61. `views` Columns

Name	Data Type	Description
table_catalog	sql_identifier	Name of the database that contains the view (always the current database)
table_schema	sql_identifier	Name of the schema that contains the view
table_name	sql_identifier	Name of the view
view_definition	character_data	Query expression defining the view (null if the view is not owned by a currently enabled role)
check_option	character_data	Applies to a feature not available in PostgreSQL
is_updatable	yes_or_no	YES if the view is updatable (allows UPDATE and DELETE), NO if not
is_insertable_into	yes_or_no	YES if the view is insertable into (allows INSERT), NO if not
is_trigger_updatable	yes_or_no	YES if the view has an INSTEAD OF UPDATE trigger defined on it, NO if not
is_trigger_deletable	yes_or_no	YES if the view has an INSTEAD OF DELETE trigger defined on it, NO if not
is_trigger_insertable_into	yes_or_no	YES if the view has an INSTEAD OF INSERT trigger defined on it, NO if not

V. Server Programming

This part is about extending the server functionality with user-defined functions, data types, triggers, etc. These are advanced topics which should probably be approached only after all the other user documentation about PostgreSQL has been understood. Later chapters in this part describe the server-side programming languages available in the PostgreSQL distribution as well as general issues concerning server-side programming languages. It is essential to read at least the earlier sections of Chapter 35 (covering functions) before diving into the material about server-side programming languages.

Chapter 35. Extending SQL

In the sections that follow, we will discuss how you can extend the PostgreSQL SQL query language by adding:

- functions (starting in Section 35.3)
- aggregates (starting in Section 35.10)
- data types (starting in Section 35.11)
- operators (starting in Section 35.12)
- operator classes for indexes (starting in Section 35.14)
- packages of related objects (starting in Section 35.15)

35.1. How Extensibility Works

PostgreSQL is extensible because its operation is catalog-driven. If you are familiar with standard relational database systems, you know that they store information about databases, tables, columns, etc., in what are commonly known as system catalogs. (Some systems call this the data dictionary.) The catalogs appear to the user as tables like any other, but the DBMS stores its internal bookkeeping in them. One key difference between PostgreSQL and standard relational database systems is that PostgreSQL stores much more information in its catalogs: not only information about tables and columns, but also information about data types, functions, access methods, and so on. These tables can be modified by the user, and since PostgreSQL bases its operation on these tables, this means that PostgreSQL can be extended by users. By comparison, conventional database systems can only be extended by changing hardcoded procedures in the source code or by loading modules specially written by the DBMS vendor.

The PostgreSQL server can moreover incorporate user-written code into itself through dynamic loading. That is, the user can specify an object code file (e.g., a shared library) that implements a new type or function, and PostgreSQL will load it as required. Code written in SQL is even more trivial to add to the server. This ability to modify its operation "on the fly" makes PostgreSQL uniquely suited for rapid prototyping of new applications and storage structures.

35.2. The PostgreSQL Type System

PostgreSQL data types are divided into base types, composite types, domains, and pseudo-types.

35.2.1. Base Types

Base types are those, like `int4`, that are implemented below the level of the SQL language (typically in a low-level language such as C). They generally correspond to what are often known as abstract data types. PostgreSQL can only operate on such types through functions provided by the user and only understands the behavior of such types to the extent that the user describes them. Base types are further subdivided into scalar and array types. For each scalar type, a corresponding array type is automatically created that can hold variable-size arrays of that scalar type.

35.2.2. Composite Types

Composite types, or row types, are created whenever the user creates a table. It is also possible to use CREATE TYPE to define a "stand-alone" composite type with no associated table. A composite type is simply a list of types with associated field names. A value of a composite type is a row or record of field values. The user can access the component fields from SQL queries. Refer to Section 8.16 for more information on composite types.

35.2.3. Domains

A domain is based on a particular base type and for many purposes is interchangeable with its base type. However, a domain can have constraints that restrict its valid values to a subset of what the underlying base type would allow.

Domains can be created using the SQL command CREATE DOMAIN. Their creation and use is not discussed in this chapter.

35.2.4. Pseudo-Types

There are a few "pseudo-types" for special purposes. Pseudo-types cannot appear as columns of tables or attributes of composite types, but they can be used to declare the argument and result types of functions. This provides a mechanism within the type system to identify special classes of functions. Table 8-25 lists the existing pseudo-types.

35.2.5. Polymorphic Types

Five pseudo-types of special interest are `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`, which are collectively called *polymorphic types*. Any function declared using these types is said to be a *polymorphic function*. A polymorphic function can operate on many different data types, with the specific data type(s) being determined by the data types actually passed to it in a particular call.

Polymorphic arguments and results are tied to each other and are resolved to a specific data type when a query calling a polymorphic function is parsed. Each position (either argument or return value) declared as `anyelement` is allowed to have any specific actual data type, but in any given call they must all be the *same* actual type. Each position declared as `anyarray` can have any array data type, but similarly they must all be the same type. And similarly, positions declared as `anyrange` must all be the same range type. Furthermore, if there are positions declared `anyarray` and others declared `anyelement`, the actual array type in the `anyarray` positions must be an array whose elements are the same type appearing in the `anyelement` positions. Similarly, if there are positions declared `anyrange` and others declared `anyelement`, the actual range type in the `anyrange` positions must be a range whose subtype is the same type appearing in the `anyelement` positions. `anynonarray` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must not be an array type. `anyenum` is treated exactly the same as `anyelement`, but adds the additional constraint that the actual type must be an enum type.

Thus, when more than one argument position is declared with a polymorphic type, the net effect is that only certain combinations of actual argument types are allowed. For example, a function declared as `equal(anyelement, anyelement)` will take any two input values, so long as they are of the same data type.

When the return value of a function is declared as a polymorphic type, there must be at least one argument position that is also polymorphic, and the actual data type supplied as the argument determines the actual result type for that call. For example, if there were not already an array subscripting mechanism, one could define a function that implements subscripting as `subscript(anyarray, integer) returns anyelement`. This declaration constrains the actual first argument to be an array type, and allows the parser to infer the correct result type from the actual first argument's type. Another example is that a function declared as `f(anyarray) returns anyenum` will only accept arrays of enum types.

Note that `anynonarray` and `anyenum` do not represent separate type variables; they are the same type as `anyelement`, just with an additional constraint. For example, declaring a function as `f(anyelement, anyenum)` is equivalent to declaring it as `f(anyenum, anyenum)`: both actual arguments have to be the same enum type.

A variadic function (one taking a variable number of arguments, as in Section 35.4.5) can be polymorphic: this is accomplished by declaring its last parameter as `VARIADIC anyarray`. For purposes of argument matching and determining the actual result type, such a function behaves the same as if you had written the appropriate number of `anynonarray` parameters.

35.3. User-defined Functions

PostgreSQL provides four kinds of functions:

- query language functions (functions written in SQL) (Section 35.4)
- procedural language functions (functions written in, for example, PL/pgSQL or PL/Tcl) (Section 35.7)
- internal functions (Section 35.8)
- C-language functions (Section 35.9)

Every kind of function can take base types, composite types, or combinations of these as arguments (parameters). In addition, every kind of function can return a base type or a composite type. Functions can also be defined to return sets of base or composite values.

Many kinds of functions can take or return certain pseudo-types (such as polymorphic types), but the available facilities vary. Consult the description of each kind of function for more details.

It's easiest to define SQL functions, so we'll start by discussing those. Most of the concepts presented for SQL functions will carry over to the other types of functions.

Throughout this chapter, it can be useful to look at the reference page of the CREATE FUNCTION command to understand the examples better. Some examples from this chapter can be found in `funcs.sql` and `funcs.c` in the `src/tutorial` directory in the PostgreSQL source distribution.

35.4. Query Language (SQL) Functions

SQL functions execute an arbitrary list of SQL statements, returning the result of the last query in the list. In the simple (non-set) case, the first row of the last query's result will be returned. (Bear in

mind that "the first row" of a multirow result is not well-defined unless you use ORDER BY.) If the last query happens to return no rows at all, the null value will be returned.

Alternatively, an SQL function can be declared to return a set (that is, multiple rows) by specifying the function's return type as SETOF *sometype*, or equivalently by declaring it as RETURNS TABLE(*columns*). In this case all rows of the last query's result are returned. Further details appear below.

The body of an SQL function must be a list of SQL statements separated by semicolons. A semicolon after the last statement is optional. Unless the function is declared to return void, the last statement must be a SELECT, or an INSERT, UPDATE, or DELETE that has a RETURNING clause.

Any collection of commands in the SQL language can be packaged together and defined as a function. Besides SELECT queries, the commands can include data modification queries (INSERT, UPDATE, and DELETE), as well as other SQL commands. (You cannot use transaction control commands, e.g. COMMIT, SAVEPOINT, and some utility commands, e.g. VACUUM, in SQL functions.) However, the final command must be a SELECT or have a RETURNING clause that returns whatever is specified as the function's return type. Alternatively, if you want to define a SQL function that performs actions but has no useful value to return, you can define it as returning void. For example, this function removes rows with negative salaries from the emp table:

```
CREATE FUNCTION clean_emp() RETURNS void AS '
    DELETE FROM emp
        WHERE salary < 0;
' LANGUAGE SQL;

SELECT clean_emp();

 clean_emp
-----------

(1 row)
```

> **Note:** The entire body of a SQL function is parsed before any of it is executed. While a SQL function can contain commands that alter the system catalogs (e.g., CREATE TABLE), the effects of such commands will not be visible during parse analysis of later commands in the function. Thus, for example, CREATE TABLE foo (...); INSERT INTO foo VALUES(...); will not work as desired if packaged up into a single SQL function, since foo won't exist yet when the INSERT command is parsed. It's recommended to use PL/PgSQL instead of a SQL function in this type of situation.

The syntax of the CREATE FUNCTION command requires the function body to be written as a string constant. It is usually most convenient to use dollar quoting (see Section 4.1.2.4) for the string constant. If you choose to use regular single-quoted string constant syntax, you must double single quote marks (') and backslashes (\) (assuming escape string syntax) in the body of the function (see Section 4.1.2.1).

35.4.1. Arguments for SQL Functions

Arguments of a SQL function can be referenced in the function body using either names or numbers. Examples of both methods appear below.

To use a name, declare the function argument as having a name, and then just write that name in the function body. If the argument name is the same as any column name in the current SQL command within the function, the column name will take precedence. To override this, qualify the argument name with the name of the function itself, that is *function_name.argument_name*. (If this would conflict with a qualified column name, again the column name wins. You can avoid the ambiguity by choosing a different alias for the table within the SQL command.)

In the older numeric approach, arguments are referenced using the syntax `$n`: `$1` refers to the first input argument, `$2` to the second, and so on. This will work whether or not the particular argument was declared with a name.

If an argument is of a composite type, then the dot notation, e.g., `argname.fieldname` or `$1.fieldname`, can be used to access attributes of the argument. Again, you might need to qualify the argument's name with the function name to make the form with an argument name unambiguous.

SQL function arguments can only be used as data values, not as identifiers. Thus for example this is reasonable:

```
INSERT INTO mytable VALUES ($1);
```

but this will not work:

```
INSERT INTO $1 VALUES (42);
```

> **Note:** The ability to use names to reference SQL function arguments was added in PostgreSQL 9.2. Functions to be used in older servers must use the `$n` notation.

35.4.2. SQL Functions on Base Types

The simplest possible SQL function has no arguments and simply returns a base type, such as `integer`:

```
CREATE FUNCTION one() RETURNS integer AS $$
    SELECT 1 AS result;
$$ LANGUAGE SQL;

-- Alternative syntax for string literal:
CREATE FUNCTION one() RETURNS integer AS '
    SELECT 1 AS result;
' LANGUAGE SQL;

SELECT one();

 one
-----
   1
```

Notice that we defined a column alias within the function body for the result of the function (with the name `result`), but this column alias is not visible outside the function. Hence, the result is labeled `one` instead of `result`.

It is almost as easy to define SQL functions that take base types as arguments:

```
CREATE FUNCTION add_em(x integer, y integer) RETURNS integer AS $$
    SELECT x + y;
$$ LANGUAGE SQL;

SELECT add_em(1, 2) AS answer;

 answer
--------
      3
```

Alternatively, we could dispense with names for the arguments and use numbers:

```
CREATE FUNCTION add_em(integer, integer) RETURNS integer AS $$
    SELECT $1 + $2;
$$ LANGUAGE SQL;

SELECT add_em(1, 2) AS answer;

 answer
--------
      3
```

Here is a more useful function, which might be used to debit a bank account:

```
CREATE FUNCTION tf1 (accountno integer, debit numeric) RETURNS integer AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tf1.accountno;
    SELECT 1;
$$ LANGUAGE SQL;
```

A user could execute this function to debit account 17 by $100.00 as follows:

```
SELECT tf1(17, 100.0);
```

In this example, we chose the name `accountno` for the first argument, but this is the same as the name of a column in the `bank` table. Within the `UPDATE` command, `accountno` refers to the column `bank.accountno`, so `tf1.accountno` must be used to refer to the argument. We could of course avoid this by using a different name for the argument.

In practice one would probably like a more useful result from the function than a constant 1, so a more likely definition is:

```
CREATE FUNCTION tf1 (accountno integer, debit numeric) RETURNS integer AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tf1.accountno;
    SELECT balance FROM bank WHERE accountno = tf1.accountno;
$$ LANGUAGE SQL;
```

which adjusts the balance and returns the new balance. The same thing could be done in one command using RETURNING:

```
CREATE FUNCTION tf1 (accountno integer, debit numeric) RETURNS integer AS $$
    UPDATE bank
        SET balance = balance - debit
        WHERE accountno = tf1.accountno
    RETURNING balance;
$$ LANGUAGE SQL;
```

35.4.3. SQL Functions on Composite Types

When writing functions with arguments of composite types, we must not only specify which argument we want but also the desired attribute (field) of that argument. For example, suppose that emp is a table containing employee data, and therefore also the name of the composite type of each row of the table. Here is a function double_salary that computes what someone's salary would be if it were doubled:

```
CREATE TABLE emp (
    name        text,
    salary      numeric,
    age         integer,
    cubicle     point
);

INSERT INTO emp VALUES ('Bill', 4200, 45, '(2,1)');

CREATE FUNCTION double_salary(emp) RETURNS numeric AS $$
    SELECT $1.salary * 2 AS salary;
$$ LANGUAGE SQL;

SELECT name, double_salary(emp.*) AS dream
    FROM emp
    WHERE emp.cubicle ~= point '(2,1)';

 name | dream
------+-------
 Bill |  8400
```

Notice the use of the syntax $1.salary to select one field of the argument row value. Also notice how the calling SELECT command uses * to select the entire current row of a table as a composite value. The table row can alternatively be referenced using just the table name, like this:

```
SELECT name, double_salary(emp) AS dream
    FROM emp
    WHERE emp.cubicle ~= point '(2,1)';
```

but this usage is deprecated since it's easy to get confused.

Sometimes it is handy to construct a composite argument value on-the-fly. This can be done with the ROW construct. For example, we could adjust the data being passed to the function:

```
SELECT name, double_salary(ROW(name, salary*1.1, age, cubicle)) AS dream
    FROM emp;
```

It is also possible to build a function that returns a composite type. This is an example of a function that returns a single `emp` row:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
    SELECT text 'None' AS name,
        1000.0 AS salary,
        25 AS age,
        point '(2,2)' AS cubicle;
$$ LANGUAGE SQL;
```

In this example we have specified each of the attributes with a constant value, but any computation could have been substituted for these constants.

Note two important things about defining the function:

- The select list order in the query must be exactly the same as that in which the columns appear in the table associated with the composite type. (Naming the columns, as we did above, is irrelevant to the system.)
- You must typecast the expressions to match the definition of the composite type, or you will get errors like this:

```
ERROR:  function declared to return emp returns varchar instead of text at column 1
```

A different way to define the same function is:

```
CREATE FUNCTION new_emp() RETURNS emp AS $$
    SELECT ROW('None', 1000.0, 25, '(2,2)')::emp;
$$ LANGUAGE SQL;
```

Here we wrote a `SELECT` that returns just a single column of the correct composite type. This isn't really better in this situation, but it is a handy alternative in some cases — for example, if we need to compute the result by calling another function that returns the desired composite value.

We could call this function directly in either of two ways:

```
SELECT new_emp();

          new_emp
--------------------------
 (None,1000.0,25,"(2,2)")

SELECT * FROM new_emp();

 name | salary | age | cubicle
------+--------+-----+---------
 None | 1000.0 |  25 | (2,2)
```

The second way is described more fully in Section 35.4.7.

When you use a function that returns a composite type, you might want only one field (attribute) from its result. You can do that with syntax like this:

```
SELECT (new_emp()).name;

 name
```

```
------
 None
```

The extra parentheses are needed to keep the parser from getting confused. If you try to do it without them, you get something like this:

```
SELECT new_emp().name;
ERROR:  syntax error at or near "."
LINE 1: SELECT new_emp().name;
                        ^
```

Another option is to use functional notation for extracting an attribute. The simple way to explain this is that we can use the notations `attribute(table)` and `table.attribute` interchangeably.

```
SELECT name(new_emp());

 name
------
 None

-- This is the same as:
-- SELECT emp.name AS youngster FROM emp WHERE emp.age < 30;

SELECT name(emp) AS youngster FROM emp WHERE age(emp) < 30;

 youngster
-----------
 Sam
 Andy
```

> **Tip:** The equivalence between functional notation and attribute notation makes it possible to use functions on composite types to emulate "computed fields". For example, using the previous definition for `double_salary(emp)`, we can write
>
> ```
> SELECT emp.name, emp.double_salary FROM emp;
> ```
>
> An application using this wouldn't need to be directly aware that `double_salary` isn't a real column of the table. (You can also emulate computed fields with views.)
>
> Because of this behavior, it's unwise to give a function that takes a single composite-type argument the same name as any of the fields of that composite type.

Another way to use a function returning a composite type is to pass the result to another function that accepts the correct row type as input:

```
CREATE FUNCTION getname(emp) RETURNS text AS $$
    SELECT $1.name;
$$ LANGUAGE SQL;

SELECT getname(new_emp());
 getname
---------
 None
```

```
(1 row)
```

Still another way to use a function that returns a composite type is to call it as a table function, as described in Section 35.4.7.

35.4.4. SQL Functions with Output Parameters

An alternative way of describing a function's results is to define it with *output parameters*, as in this example:

```
CREATE FUNCTION add_em (IN x int, IN y int, OUT sum int)
AS 'SELECT x + y'
LANGUAGE SQL;

SELECT add_em(3,7);
 add_em
--------
     10
(1 row)
```

This is not essentially different from the version of `add_em` shown in Section 35.4.2. The real value of output parameters is that they provide a convenient way of defining functions that return several columns. For example,

```
CREATE FUNCTION sum_n_product (x int, y int, OUT sum int, OUT product int)
AS 'SELECT x + y, x * y'
LANGUAGE SQL;

 SELECT * FROM sum_n_product(11,42);
 sum | product
-----+---------
  53 |     462
(1 row)
```

What has essentially happened here is that we have created an anonymous composite type for the result of the function. The above example has the same end result as

```
CREATE TYPE sum_prod AS (sum int, product int);

CREATE FUNCTION sum_n_product (int, int) RETURNS sum_prod
AS 'SELECT $1 + $2, $1 * $2'
LANGUAGE SQL;
```

but not having to bother with the separate composite type definition is often handy. Notice that the names attached to the output parameters are not just decoration, but determine the column names of the anonymous composite type. (If you omit a name for an output parameter, the system will choose a name on its own.)

Notice that output parameters are not included in the calling argument list when invoking such a function from SQL. This is because PostgreSQL considers only the input parameters to define the function's calling signature. That means also that only the input parameters matter when referencing the function for purposes such as dropping it. We could drop the above function with either of

```
DROP FUNCTION sum_n_product (x int, y int, OUT sum int, OUT product int);
```

```
DROP FUNCTION sum_n_product (int, int);
```

Parameters can be marked as IN (the default), OUT, INOUT, or VARIADIC. An INOUT parameter serves as both an input parameter (part of the calling argument list) and an output parameter (part of the result record type). VARIADIC parameters are input parameters, but are treated specially as described next.

35.4.5. SQL Functions with Variable Numbers of Arguments

SQL functions can be declared to accept variable numbers of arguments, so long as all the "optional" arguments are of the same data type. The optional arguments will be passed to the function as an array. The function is declared by marking the last parameter as VARIADIC; this parameter must be declared as being of an array type. For example:

```
CREATE FUNCTION mleast(VARIADIC arr numeric[]) RETURNS numeric AS $$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;

SELECT mleast(10, -1, 5, 4.4);
 mleast
--------
     -1
(1 row)
```

Effectively, all the actual arguments at or beyond the VARIADIC position are gathered up into a one-dimensional array, as if you had written

```
SELECT mleast(ARRAY[10, -1, 5, 4.4]);    -- doesn't work
```

You can't actually write that, though — or at least, it will not match this function definition. A parameter marked VARIADIC matches one or more occurrences of its element type, not of its own type.

Sometimes it is useful to be able to pass an already-constructed array to a variadic function; this is particularly handy when one variadic function wants to pass on its array parameter to another one. You can do that by specifying VARIADIC in the call:

```
SELECT mleast(VARIADIC ARRAY[10, -1, 5, 4.4]);
```

This prevents expansion of the function's variadic parameter into its element type, thereby allowing the array argument value to match normally. VARIADIC can only be attached to the last actual argument of a function call.

Specifying VARIADIC in the call is also the only way to pass an empty array to a variadic function, for example:

```
SELECT mleast(VARIADIC ARRAY[]::numeric[]);
```

Simply writing SELECT mleast() does not work because a variadic parameter must match at least one actual argument. (You could define a second function also named mleast, with no parameters, if you wanted to allow such calls.)

The array element parameters generated from a variadic parameter are treated as not having any names of their own. This means it is not possible to call a variadic function using named arguments (Section 4.3), except when you specify VARIADIC. For example, this will work:

```
SELECT mleast(VARIADIC arr := ARRAY[10, -1, 5, 4.4]);
```

but not these:

```
SELECT mleast(arr := 10);
SELECT mleast(arr := ARRAY[10, -1, 5, 4.4]);
```

35.4.6. SQL Functions with Default Values for Arguments

Functions can be declared with default values for some or all input arguments. The default values are inserted whenever the function is called with insufficiently many actual arguments. Since arguments can only be omitted from the end of the actual argument list, all parameters after a parameter with a default value have to have default values as well. (Although the use of named argument notation could allow this restriction to be relaxed, it's still enforced so that positional argument notation works sensibly.)

For example:

```
CREATE FUNCTION foo(a int, b int DEFAULT 2, c int DEFAULT 3)
RETURNS int
LANGUAGE SQL
AS $$
    SELECT $1 + $2 + $3;
$$;

SELECT foo(10, 20, 30);
 foo
-----
  60
(1 row)

SELECT foo(10, 20);
 foo
-----
  33
(1 row)

SELECT foo(10);
 foo
-----
  15
(1 row)

SELECT foo();  -- fails since there is no default for the first argument
ERROR:  function foo() does not exist
```

The = sign can also be used in place of the key word `DEFAULT`.

35.4.7. SQL Functions as Table Sources

All SQL functions can be used in the FROM clause of a query, but it is particularly useful for functions returning composite types. If the function is defined to return a base type, the table function produces a one-column table. If the function is defined to return a composite type, the table function produces a column for each attribute of the composite type.

Here is an example:

```
CREATE TABLE foo (fooid int, foosubid int, fooname text);
INSERT INTO foo VALUES (1, 1, 'Joe');
INSERT INTO foo VALUES (1, 2, 'Ed');
INSERT INTO foo VALUES (2, 1, 'Mary');

CREATE FUNCTION getfoo(int) RETURNS foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;

SELECT *, upper(fooname) FROM getfoo(1) AS t1;

 fooid | foosubid | fooname | upper
-------+----------+---------+-------
     1 |        1 | Joe     | JOE
(1 row)
```

As the example shows, we can work with the columns of the function's result just the same as if they were columns of a regular table.

Note that we only got one row out of the function. This is because we did not use SETOF. That is described in the next section.

35.4.8. SQL Functions Returning Sets

When an SQL function is declared as returning SETOF *sometype*, the function's final query is executed to completion, and each row it outputs is returned as an element of the result set.

This feature is normally used when calling the function in the FROM clause. In this case each row returned by the function becomes a row of the table seen by the query. For example, assume that table foo has the same contents as above, and we say:

```
CREATE FUNCTION getfoo(int) RETURNS SETOF foo AS $$
    SELECT * FROM foo WHERE fooid = $1;
$$ LANGUAGE SQL;

SELECT * FROM getfoo(1) AS t1;
```

Then we would get:

```
 fooid | foosubid | fooname
-------+----------+---------
     1 |        1 | Joe
     1 |        2 | Ed
(2 rows)
```

It is also possible to return multiple rows with the columns defined by output parameters, like this:

```
CREATE TABLE tab (y int, z int);
INSERT INTO tab VALUES (1, 2), (3, 4), (5, 6), (7, 8);

CREATE FUNCTION sum_n_product_with_tab (x int, OUT sum int, OUT product int)
RETURNS SETOF record
AS $$
    SELECT $1 + tab.y, $1 * tab.y FROM tab;
$$ LANGUAGE SQL;

SELECT * FROM sum_n_product_with_tab(10);
 sum | product
-----+---------
  11 |      10
  13 |      30
  15 |      50
  17 |      70
(4 rows)
```

The key point here is that you must write `RETURNS SETOF record` to indicate that the function returns multiple rows instead of just one. If there is only one output parameter, write that parameter's type instead of `record`.

It is frequently useful to construct a query's result by invoking a set-returning function multiple times, with the parameters for each invocation coming from successive rows of a table or subquery. The preferred way to do this is to use the `LATERAL` key word, which is described in Section 7.2.1.5. Here is an example using a set-returning function to enumerate elements of a tree structure:

```
SELECT * FROM nodes;
   name    | parent
-----------+--------
 Top       |
 Child1    | Top
 Child2    | Top
 Child3    | Top
 SubChild1 | Child1
 SubChild2 | Child1
(6 rows)

CREATE FUNCTION listchildren(text) RETURNS SETOF text AS $$
    SELECT name FROM nodes WHERE parent = $1
$$ LANGUAGE SQL STABLE;

SELECT * FROM listchildren('Top');
 listchildren
--------------
 Child1
 Child2
 Child3
(3 rows)

SELECT name, child FROM nodes, LATERAL listchildren(name) AS child;
  name  |   child
--------+-----------
 Top    | Child1
 Top    | Child2
 Top    | Child3
 Child1 | SubChild1
```

```
 Child1 | SubChild2
(5 rows)
```

This example does not do anything that we couldn't have done with a simple join, but in more complex calculations the option to put some of the work into a function can be quite convenient.

Currently, functions returning sets can also be called in the select list of a query. For each row that the query generates by itself, the function returning set is invoked, and an output row is generated for each element of the function's result set. Note, however, that this capability is deprecated and might be removed in future releases. The previous example could also be done with queries like these:

```
SELECT listchildren('Top');
 listchildren
--------------
 Child1
 Child2
 Child3
(3 rows)

SELECT name, listchildren(name) FROM nodes;
  name   | listchildren
---------+--------------
 Top     | Child1
 Top     | Child2
 Top     | Child3
 Child1  | SubChild1
 Child1  | SubChild2
(5 rows)
```

In the last `SELECT`, notice that no output row appears for `Child2`, `Child3`, etc. This happens because `listchildren` returns an empty set for those arguments, so no result rows are generated. This is the same behavior as we got from an inner join to the function result when using the `LATERAL` syntax.

> **Note:** If a function's last command is `INSERT`, `UPDATE`, or `DELETE` with `RETURNING`, that command will always be executed to completion, even if the function is not declared with `SETOF` or the calling query does not fetch all the result rows. Any extra rows produced by the `RETURNING` clause are silently dropped, but the commanded table modifications still happen (and are all completed before returning from the function).

> **Note:** The key problem with using set-returning functions in the select list, rather than the `FROM` clause, is that putting more than one set-returning function in the same select list does not behave very sensibly. (What you actually get if you do so is a number of output rows equal to the least common multiple of the numbers of rows produced by each set-returning function.) The `LATERAL` syntax produces less surprising results when calling multiple set-returning functions, and should usually be used instead.

35.4.9. SQL Functions Returning `TABLE`

There is another way to declare a function as returning a set, which is to use the syntax `RETURNS TABLE(`*`columns`*`)`. This is equivalent to using one or more `OUT` parameters plus marking the function

as returning SETOF record (or SETOF a single output parameter's type, as appropriate). This notation is specified in recent versions of the SQL standard, and thus may be more portable than using SETOF.

For example, the preceding sum-and-product example could also be done this way:

```
CREATE FUNCTION sum_n_product_with_tab (x int)
RETURNS TABLE(sum int, product int) AS $$
    SELECT $1 + tab.y, $1 * tab.y FROM tab;
$$ LANGUAGE SQL;
```

It is not allowed to use explicit OUT or INOUT parameters with the RETURNS TABLE notation — you must put all the output columns in the TABLE list.

35.4.10. Polymorphic SQL Functions

SQL functions can be declared to accept and return the polymorphic types anyelement, anyarray, anynonarray, anyenum, and anyrange. See Section 35.2.5 for a more detailed explanation of polymorphic functions. Here is a polymorphic function make_array that builds up an array from two arbitrary data type elements:

```
CREATE FUNCTION make_array(anyelement, anyelement) RETURNS anyarray AS $$
    SELECT ARRAY[$1, $2];
$$ LANGUAGE SQL;

SELECT make_array(1, 2) AS intarray, make_array('a'::text, 'b') AS textarray;
 intarray | textarray
----------+-----------
 {1,2}    | {a,b}
(1 row)
```

Notice the use of the typecast 'a'::text to specify that the argument is of type text. This is required if the argument is just a string literal, since otherwise it would be treated as type unknown, and array of unknown is not a valid type. Without the typecast, you will get errors like this:

```
ERROR:  could not determine polymorphic type because input has type "unknown"
```

It is permitted to have polymorphic arguments with a fixed return type, but the converse is not. For example:

```
CREATE FUNCTION is_greater(anyelement, anyelement) RETURNS boolean AS $$
    SELECT $1 > $2;
$$ LANGUAGE SQL;

SELECT is_greater(1, 2);
 is_greater
------------
 f
(1 row)

CREATE FUNCTION invalid_func() RETURNS anyelement AS $$
    SELECT 1;
$$ LANGUAGE SQL;
```

```
ERROR:  cannot determine result data type
DETAIL:  A function returning a polymorphic type must have at least one polymorphic argu
```

Polymorphism can be used with functions that have output arguments. For example:

```
CREATE FUNCTION dup (f1 anyelement, OUT f2 anyelement, OUT f3 anyarray)
AS 'select $1, array[$1,$1]' LANGUAGE SQL;

SELECT * FROM dup(22);
 f2 |   f3
----+---------
 22 | {22,22}
(1 row)
```

Polymorphism can also be used with variadic functions. For example:

```
CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS $$
    SELECT min($1[i]) FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;

SELECT anyleast(10, -1, 5, 4);
 anyleast
----------
       -1
(1 row)

SELECT anyleast('abc'::text, 'def');
 anyleast
----------
 abc
(1 row)

CREATE FUNCTION concat_values(text, VARIADIC anyarray) RETURNS text AS $$
    SELECT array_to_string($2, $1);
$$ LANGUAGE SQL;

SELECT concat_values('|', 1, 4, 2);
 concat_values
---------------
 1|4|2
(1 row)
```

35.4.11. SQL Functions with Collations

When a SQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 22.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly.

This will affect the behavior of collation-sensitive operations within the function. For example, using the `anyleast` function described above, the result of

```
SELECT anyleast('abc'::text, 'ABC');
```

will depend on the database's default collation. In `C` locale the result will be `ABC`, but in many other locales it will be `abc`. The collation to use can be forced by adding a `COLLATE` clause to any of the arguments, for example

```
SELECT anyleast('abc'::text, 'ABC' COLLATE "C");
```

Alternatively, if you wish a function to operate with a particular collation regardless of what it is called with, insert `COLLATE` clauses as needed in the function definition. This version of `anyleast` would always use `en_US` locale to compare strings:

```
CREATE FUNCTION anyleast (VARIADIC anyarray) RETURNS anyelement AS $$
    SELECT min($1[i] COLLATE "en_US") FROM generate_subscripts($1, 1) g(i);
$$ LANGUAGE SQL;
```

But note that this will throw an error if applied to a non-collatable data type.

If no common collation can be identified among the actual arguments, then a SQL function treats its parameters as having their data types' default collation (which is usually the database's default collation, but could be different for parameters of domain types).

The behavior of collatable parameters can be thought of as a limited form of polymorphism, applicable only to textual data types.

35.5. Function Overloading

More than one function can be defined with the same SQL name, so long as the arguments they take are different. In other words, function names can be *overloaded*. When a query is executed, the server will determine which function to call from the data types and the number of the provided arguments. Overloading can also be used to simulate functions with a variable number of arguments, up to a finite maximum number.

When creating a family of overloaded functions, one should be careful not to create ambiguities. For instance, given the functions:

```
CREATE FUNCTION test(int, real) RETURNS ...
CREATE FUNCTION test(smallint, double precision) RETURNS ...
```

it is not immediately clear which function would be called with some trivial input like `test(1, 1.5)`. The currently implemented resolution rules are described in Chapter 10, but it is unwise to design a system that subtly relies on this behavior.

A function that takes a single argument of a composite type should generally not have the same name as any attribute (field) of that type. Recall that `attribute(table)` is considered equivalent to `table.attribute`. In the case that there is an ambiguity between a function on a composite type and an attribute of the composite type, the attribute will always be used. It is possible to override that choice by schema-qualifying the function name (that is, `schema.func(table)`) but it's better to avoid the problem by not choosing conflicting names.

Another possible conflict is between variadic and non-variadic functions. For instance, it is possible to create both `foo(numeric)` and `foo(VARIADIC numeric[])`. In this case it is unclear which

one should be matched to a call providing a single numeric argument, such as `foo(10.1)`. The rule is that the function appearing earlier in the search path is used, or if the two functions are in the same schema, the non-variadic one is preferred.

When overloading C-language functions, there is an additional constraint: The C name of each function in the family of overloaded functions must be different from the C names of all other functions, either internal or dynamically loaded. If this rule is violated, the behavior is not portable. You might get a run-time linker error, or one of the functions will get called (usually the internal one). The alternative form of the `AS` clause for the SQL `CREATE FUNCTION` command decouples the SQL function name from the function name in the C source code. For instance:

```
CREATE FUNCTION test(int) RETURNS int
    AS 'filename', 'test_1arg'
    LANGUAGE C;
CREATE FUNCTION test(int, int) RETURNS int
    AS 'filename', 'test_2arg'
    LANGUAGE C;
```

The names of the C functions here reflect one of many possible conventions.

35.6. Function Volatility Categories

Every function has a *volatility* classification, with the possibilities being `VOLATILE`, `STABLE`, or `IMMUTABLE`. `VOLATILE` is the default if the CREATE FUNCTION command does not specify a category. The volatility category is a promise to the optimizer about the behavior of the function:

- A `VOLATILE` function can do anything, including modifying the database. It can return different results on successive calls with the same arguments. The optimizer makes no assumptions about the behavior of such functions. A query using a volatile function will re-evaluate the function at every row where its value is needed.
- A `STABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments for all rows within a single statement. This category allows the optimizer to optimize multiple calls of the function to a single call. In particular, it is safe to use an expression containing such a function in an index scan condition. (Since an index scan will evaluate the comparison value only once, not once at each row, it is not valid to use a `VOLATILE` function in an index scan condition.)
- An `IMMUTABLE` function cannot modify the database and is guaranteed to return the same results given the same arguments forever. This category allows the optimizer to pre-evaluate the function when a query calls it with constant arguments. For example, a query like `SELECT ... WHERE x = 2 + 2` can be simplified on sight to `SELECT ... WHERE x = 4`, because the function underlying the integer addition operator is marked `IMMUTABLE`.

For best optimization results, you should label your functions with the strictest volatility category that is valid for them.

Any function with side-effects *must* be labeled `VOLATILE`, so that calls to it cannot be optimized away. Even a function with no side-effects needs to be labeled `VOLATILE` if its value can change within a single query; some examples are `random()`, `currval()`, `timeofday()`.

Another important example is that the `current_timestamp` family of functions qualify as `STABLE`, since their values do not change within a transaction.

There is relatively little difference between `STABLE` and `IMMUTABLE` categories when considering simple interactive queries that are planned and immediately executed: it doesn't matter a lot whether a function is executed once during planning or once during query execution startup. But there is a big difference if the plan is saved and reused later. Labeling a function `IMMUTABLE` when it really isn't might allow it to be prematurely folded to a constant during planning, resulting in a stale value being re-used during subsequent uses of the plan. This is a hazard when using prepared statements or when using function languages that cache plans (such as PL/pgSQL).

For functions written in SQL or in any of the standard procedural languages, there is a second important property determined by the volatility category, namely the visibility of any data changes that have been made by the SQL command that is calling the function. A `VOLATILE` function will see such changes, a `STABLE` or `IMMUTABLE` function will not. This behavior is implemented using the snapshotting behavior of MVCC (see Chapter 13): `STABLE` and `IMMUTABLE` functions use a snapshot established as of the start of the calling query, whereas `VOLATILE` functions obtain a fresh snapshot at the start of each query they execute.

> **Note:** Functions written in C can manage snapshots however they want, but it's usually a good idea to make C functions work this way too.

Because of this snapshotting behavior, a function containing only `SELECT` commands can safely be marked `STABLE`, even if it selects from tables that might be undergoing modifications by concurrent queries. PostgreSQL will execute all commands of a `STABLE` function using the snapshot established for the calling query, and so it will see a fixed view of the database throughout that query.

The same snapshotting behavior is used for `SELECT` commands within `IMMUTABLE` functions. It is generally unwise to select from database tables within an `IMMUTABLE` function at all, since the immutability will be broken if the table contents ever change. However, PostgreSQL does not enforce that you do not do that.

A common error is to label a function `IMMUTABLE` when its results depend on a configuration parameter. For example, a function that manipulates timestamps might well have results that depend on the TimeZone setting. For safety, such functions should be labeled `STABLE` instead.

> **Note:** PostgreSQL requires that `STABLE` and `IMMUTABLE` functions contain no SQL commands other than `SELECT` to prevent data modification. (This is not a completely bulletproof test, since such functions could still call `VOLATILE` functions that modify the database. If you do that, you will find that the `STABLE` or `IMMUTABLE` function does not notice the database changes applied by the called function, since they are hidden from its snapshot.)

35.7. Procedural Language Functions

PostgreSQL allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). Procedural languages aren't built into the PostgreSQL server; they are offered by loadable modules. See Chapter 39 and following chapters for more information.

35.8. Internal Functions

Internal functions are functions written in C that have been statically linked into the PostgreSQL server. The "body" of the function definition specifies the C-language name of the function, which need not be the same as the name being declared for SQL use. (For reasons of backward compatibility, an empty body is accepted as meaning that the C-language function name is the same as the SQL name.)

Normally, all internal functions present in the server are declared during the initialization of the database cluster (see Section 17.2), but a user could use `CREATE FUNCTION` to create additional alias names for an internal function. Internal functions are declared in `CREATE FUNCTION` with language name `internal`. For instance, to create an alias for the `sqrt` function:

```
CREATE FUNCTION square_root(double precision) RETURNS double precision
    AS 'dsqrt'
    LANGUAGE internal
    STRICT;
```

(Most internal functions expect to be declared "strict".)

> **Note:** Not all "predefined" functions are "internal" in the above sense. Some predefined functions are written in SQL.

35.9. C-Language Functions

User-defined functions can be written in C (or a language that can be made compatible with C, such as C++). Such functions are compiled into dynamically loadable objects (also called shared libraries) and are loaded by the server on demand. The dynamic loading feature is what distinguishes "C language" functions from "internal" functions — the actual coding conventions are essentially the same for both. (Hence, the standard internal function library is a rich source of coding examples for user-defined C functions.)

Two different calling conventions are currently used for C functions. The newer "version 1" calling convention is indicated by writing a `PG_FUNCTION_INFO_V1()` macro call for the function, as illustrated below. Lack of such a macro indicates an old-style ("version 0") function. The language name specified in `CREATE FUNCTION` is `C` in either case. Old-style functions are now deprecated because of portability problems and lack of functionality, but they are still supported for compatibility reasons.

35.9.1. Dynamic Loading

The first time a user-defined function in a particular loadable object file is called in a session, the dynamic loader loads that object file into memory so that the function can be called. The `CREATE FUNCTION` for a user-defined C function must therefore specify two pieces of information for the function: the name of the loadable object file, and the C name (link symbol) of the specific function to call within that object file. If the C name is not explicitly specified then it is assumed to be the same as the SQL function name.

The following algorithm is used to locate the shared object file based on the name given in the `CREATE FUNCTION` command:

1. If the name is an absolute path, the given file is loaded.
2. If the name starts with the string `$libdir`, that part is replaced by the PostgreSQL package library directory name, which is determined at build time.
3. If the name does not contain a directory part, the file is searched for in the path specified by the configuration variable dynamic_library_path.
4. Otherwise (the file was not found in the path, or it contains a non-absolute directory part), the dynamic loader will try to take the name as given, which will most likely fail. (It is unreliable to depend on the current working directory.)

If this sequence does not work, the platform-specific shared library file name extension (often `.so`) is appended to the given name and this sequence is tried again. If that fails as well, the load will fail.

It is recommended to locate shared libraries either relative to `$libdir` or through the dynamic library path. This simplifies version upgrades if the new installation is at a different location. The actual directory that `$libdir` stands for can be found out with the command `pg_config --pkglibdir`.

The user ID the PostgreSQL server runs as must be able to traverse the path to the file you intend to load. Making the file or a higher-level directory not readable and/or not executable by the postgres user is a common mistake.

In any case, the file name that is given in the `CREATE FUNCTION` command is recorded literally in the system catalogs, so if the file needs to be loaded again the same procedure is applied.

> **Note:** PostgreSQL will not compile a C function automatically. The object file must be compiled before it is referenced in a `CREATE FUNCTION` command. See Section 35.9.6 for additional information.

To ensure that a dynamically loaded object file is not loaded into an incompatible server, PostgreSQL checks that the file contains a "magic block" with the appropriate contents. This allows the server to detect obvious incompatibilities, such as code compiled for a different major version of PostgreSQL. A magic block is required as of PostgreSQL 8.2. To include a magic block, write this in one (and only one) of the module source files, after having included the header `fmgr.h`:

```
#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif
```

The `#ifdef` test can be omitted if the code doesn't need to compile against pre-8.2 PostgreSQL releases.

After it is used for the first time, a dynamically loaded object file is retained in memory. Future calls in the same session to the function(s) in that file will only incur the small overhead of a symbol table lookup. If you need to force a reload of an object file, for example after recompiling it, begin a fresh session.

Optionally, a dynamically loaded file can contain initialization and finalization functions. If the file includes a function named `_PG_init`, that function will be called immediately after loading the file. The function receives no parameters and should return void. If the file includes a function named `_PG_fini`, that function will be called immediately before unloading the file. Likewise, the function receives no parameters and should return void. Note that `_PG_fini` will only be called during an unload of the file, not during process termination. (Presently, unloads are disabled and will never occur, but this may change in the future.)

35.9.2. Base Types in C-Language Functions

To know how to write C-language functions, you need to know how PostgreSQL internally represents base data types and how they can be passed to and from functions. Internally, PostgreSQL regards a base type as a "blob of memory". The user-defined functions that you define over a type in turn define the way that PostgreSQL can operate on it. That is, PostgreSQL will only store and retrieve the data from disk and use your user-defined functions to input, process, and output the data.

Base types can have one of three internal formats:

- pass by value, fixed-length
- pass by reference, fixed-length
- pass by reference, variable-length

By-value types can only be 1, 2, or 4 bytes in length (also 8 bytes, if `sizeof(Datum)` is 8 on your machine). You should be careful to define your types such that they will be the same size (in bytes) on all architectures. For example, the `long` type is dangerous because it is 4 bytes on some machines and 8 bytes on others, whereas `int` type is 4 bytes on most Unix machines. A reasonable implementation of the `int4` type on Unix machines might be:

```
/* 4-byte integer, passed by value */
typedef int int4;
```

(The actual PostgreSQL C code calls this type `int32`, because it is a convention in C that `int`*XX* means *XX bits*. Note therefore also that the C type `int8` is 1 byte in size. The SQL type `int8` is called `int64` in C. See also Table 35-1.)

On the other hand, fixed-length types of any size can be passed by-reference. For example, here is a sample implementation of a PostgreSQL type:

```
/* 16-byte structure, passed by reference */
typedef struct
{
    double  x, y;
} Point;
```

Only pointers to such types can be used when passing them in and out of PostgreSQL functions. To return a value of such a type, allocate the right amount of memory with `palloc`, fill in the allocated memory, and return a pointer to it. (Also, if you just want to return the same value as one of your input arguments that's of the same data type, you can skip the extra `palloc` and just return the pointer to the input value.)

Finally, all variable-length types must also be passed by reference. All variable-length types must begin with an opaque length field of exactly 4 bytes, which will be set by `SET_VARSIZE`; never set this field directly! All data to be stored within that type must be located in the memory immediately following that length field. The length field contains the total length of the structure, that is, it includes the size of the length field itself.

Another important point is to avoid leaving any uninitialized bits within data type values; for example, take care to zero out any alignment padding bytes that might be present in structs. Without this, logically-equivalent constants of your data type might be seen as unequal by the planner, leading to inefficient (though not incorrect) plans.

> **Warning**
>
> *Never* modify the contents of a pass-by-reference input value. If you do so you are likely to corrupt on-disk data, since the pointer you are given might point directly into a disk buffer. The sole exception to this rule is explained in Section 35.10.

As an example, we can define the type `text` as follows:

```
typedef struct {
    int32 length;
    char data[1];
} text;
```

Obviously, the data field declared here is not long enough to hold all possible strings. Since it's impossible to declare a variable-size structure in C, we rely on the knowledge that the C compiler won't range-check array subscripts. We just allocate the necessary amount of space and then access the array as if it were declared the right length. (This is a common trick, which you can read about in many textbooks about C.)

When manipulating variable-length types, we must be careful to allocate the correct amount of memory and set the length field correctly. For example, if we wanted to store 40 bytes in a `text` structure, we might use a code fragment like this:

```
#include "postgres.h"
...
char buffer[40]; /* our source data */
...
text *destination = (text *) palloc(VARHDRSZ + 40);
SET_VARSIZE(destination, VARHDRSZ + 40);
memcpy(destination->data, buffer, 40);
...
```

`VARHDRSZ` is the same as `sizeof(int32)`, but it's considered good style to use the macro `VARHDRSZ` to refer to the size of the overhead for a variable-length type. Also, the length field *must* be set using the `SET_VARSIZE` macro, not by simple assignment.

Table 35-1 specifies which C type corresponds to which SQL type when writing a C-language function that uses a built-in type of PostgreSQL. The "Defined In" column gives the header file that needs to be included to get the type definition. (The actual definition might be in a different file that is included by the listed file. It is recommended that users stick to the defined interface.) Note that you should always include `postgres.h` first in any source file, because it declares a number of things that you will need anyway.

Table 35-1. Equivalent C Types for Built-in SQL Types

SQL Type	C Type	Defined In
abstime	AbsoluteTime	utils/nabstime.h
boolean	bool	postgres.h (maybe compiler built-in)
box	BOX*	utils/geo_decls.h
bytea	bytea*	postgres.h
"char"	char	(compiler built-in)

SQL Type	C Type	Defined In
character	BpChar*	postgres.h
cid	CommandId	postgres.h
date	DateADT	utils/date.h
smallint (int2)	int16	postgres.h
int2vector	int2vector*	postgres.h
integer (int4)	int32	postgres.h
real (float4)	float4*	postgres.h
double precision (float8)	float8*	postgres.h
interval	Interval*	datatype/timestamp.h
lseg	LSEG*	utils/geo_decls.h
name	Name	postgres.h
oid	Oid	postgres.h
oidvector	oidvector*	postgres.h
path	PATH*	utils/geo_decls.h
point	POINT*	utils/geo_decls.h
regproc	regproc	postgres.h
reltime	RelativeTime	utils/nabstime.h
text	text*	postgres.h
tid	ItemPointer	storage/itemptr.h
time	TimeADT	utils/date.h
time with time zone	TimeTzADT	utils/date.h
timestamp	Timestamp*	datatype/timestamp.h
tinterval	TimeInterval	utils/nabstime.h
varchar	VarChar*	postgres.h
xid	TransactionId	postgres.h

Now that we've gone over all of the possible structures for base types, we can show some examples of real functions.

35.9.3. Version 0 Calling Conventions

We present the "old style" calling convention first — although this approach is now deprecated, it's easier to get a handle on initially. In the version-0 method, the arguments and result of the C function are just declared in normal C style, but being careful to use the C representation of each SQL data type as shown above.

Here are some examples:

```
#include "postgres.h"
#include <string.h>
#include "utils/geo_decls.h"

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif
```

```
/* by value */

int
add_one(int arg)
{
    return arg + 1;
}

/* by reference, fixed length */

float8 *
add_one_float8(float8 *arg)
{
    float8    *result = (float8 *) palloc(sizeof(float8));

    *result = *arg + 1.0;

    return result;
}

Point *
makepoint(Point *pointx, Point *pointy)
{
    Point     *new_point = (Point *) palloc(sizeof(Point));

    new_point->x = pointx->x;
    new_point->y = pointy->y;

    return new_point;
}

/* by reference, variable length */

text *
copytext(text *t)
{
    /*
     * VARSIZE is the total size of the struct in bytes.
     */
    text *new_t = (text *) palloc(VARSIZE(t));
    SET_VARSIZE(new_t, VARSIZE(t));
    /*
     * VARDATA is a pointer to the data region of the struct.
     */
    memcpy((void *) VARDATA(new_t), /* destination */
           (void *) VARDATA(t),     /* source */
           VARSIZE(t) - VARHDRSZ);  /* how many bytes */
    return new_t;
}

text *
concat_text(text *arg1, text *arg2)
{
    int32 new_text_size = VARSIZE(arg1) + VARSIZE(arg2) - VARHDRSZ;
    text *new_text = (text *) palloc(new_text_size);
```

```
    SET_VARSIZE(new_text, new_text_size);
    memcpy(VARDATA(new_text), VARDATA(arg1), VARSIZE(arg1) - VARHDRSZ);
    memcpy(VARDATA(new_text) + (VARSIZE(arg1) - VARHDRSZ),
           VARDATA(arg2), VARSIZE(arg2) - VARHDRSZ);
    return new_text;
}
```

Supposing that the above code has been prepared in file `funcs.c` and compiled into a shared object, we could define the functions to PostgreSQL with commands like this:

```
CREATE FUNCTION add_one(integer) RETURNS integer
     AS 'DIRECTORY/funcs', 'add_one'
     LANGUAGE C STRICT;

-- note overloading of SQL function name "add_one"
CREATE FUNCTION add_one(double precision) RETURNS double precision
     AS 'DIRECTORY/funcs', 'add_one_float8'
     LANGUAGE C STRICT;

CREATE FUNCTION makepoint(point, point) RETURNS point
     AS 'DIRECTORY/funcs', 'makepoint'
     LANGUAGE C STRICT;

CREATE FUNCTION copytext(text) RETURNS text
     AS 'DIRECTORY/funcs', 'copytext'
     LANGUAGE C STRICT;

CREATE FUNCTION concat_text(text, text) RETURNS text
     AS 'DIRECTORY/funcs', 'concat_text'
     LANGUAGE C STRICT;
```

Here, *DIRECTORY* stands for the directory of the shared library file (for instance the PostgreSQL tutorial directory, which contains the code for the examples used in this section). (Better style would be to use just `'funcs'` in the `AS` clause, after having added *DIRECTORY* to the search path. In any case, we can omit the system-specific extension for a shared library, commonly `.so` or `.sl`.)

Notice that we have specified the functions as "strict", meaning that the system should automatically assume a null result if any input value is null. By doing this, we avoid having to check for null inputs in the function code. Without this, we'd have to check for null values explicitly, by checking for a null pointer for each pass-by-reference argument. (For pass-by-value arguments, we don't even have a way to check!)

Although this calling convention is simple to use, it is not very portable; on some architectures there are problems with passing data types that are smaller than `int` this way. Also, there is no simple way to return a null result, nor to cope with null arguments in any way other than making the function strict. The version-1 convention, presented next, overcomes these objections.

35.9.4. Version 1 Calling Conventions

The version-1 calling convention relies on macros to suppress most of the complexity of passing arguments and results. The C declaration of a version-1 function is always:

```
Datum funcname(PG_FUNCTION_ARGS)
```

In addition, the macro call:

```
PG_FUNCTION_INFO_V1(funcname);
```

must appear in the same source file. (Conventionally, it's written just before the function itself.) This macro call is not needed for `internal`-language functions, since PostgreSQL assumes that all internal functions use the version-1 convention. It is, however, required for dynamically-loaded functions.

In a version-1 function, each actual argument is fetched using a `PG_GETARG_`*xxx*`()` macro that corresponds to the argument's data type, and the result is returned using a `PG_RETURN_`*xxx*`()` macro for the return type. `PG_GETARG_`*xxx*`()` takes as its argument the number of the function argument to fetch, where the count starts at 0. `PG_RETURN_`*xxx*`()` takes as its argument the actual value to return.

Here we show the same functions as above, coded in version-1 style:

```
#include "postgres.h"
#include <string.h>
#include "fmgr.h"
#include "utils/geo_decls.h"

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif

/* by value */

PG_FUNCTION_INFO_V1(add_one);

Datum
add_one(PG_FUNCTION_ARGS)
{
    int32   arg = PG_GETARG_INT32(0);

    PG_RETURN_INT32(arg + 1);
}

/* by reference, fixed length */

PG_FUNCTION_INFO_V1(add_one_float8);

Datum
add_one_float8(PG_FUNCTION_ARGS)
{
    /* The macros for FLOAT8 hide its pass-by-reference nature. */
    float8   arg = PG_GETARG_FLOAT8(0);

    PG_RETURN_FLOAT8(arg + 1.0);
}

PG_FUNCTION_INFO_V1(makepoint);

Datum
makepoint(PG_FUNCTION_ARGS)
{
    /* Here, the pass-by-reference nature of Point is not hidden. */
    Point     *pointx = PG_GETARG_POINT_P(0);
    Point     *pointy = PG_GETARG_POINT_P(1);
    Point     *new_point = (Point *) palloc(sizeof(Point));
```

```
    new_point->x = pointx->x;
    new_point->y = pointy->y;

    PG_RETURN_POINT_P(new_point);
}

/* by reference, variable length */

PG_FUNCTION_INFO_V1(copytext);

Datum
copytext(PG_FUNCTION_ARGS)
{
    text     *t = PG_GETARG_TEXT_P(0);
    /*
     * VARSIZE is the total size of the struct in bytes.
     */
    text     *new_t = (text *) palloc(VARSIZE(t));
    SET_VARSIZE(new_t, VARSIZE(t));
    /*
     * VARDATA is a pointer to the data region of the struct.
     */
    memcpy((void *) VARDATA(new_t), /* destination */
           (void *) VARDATA(t),     /* source */
           VARSIZE(t) - VARHDRSZ);  /* how many bytes */
    PG_RETURN_TEXT_P(new_t);
}

PG_FUNCTION_INFO_V1(concat_text);

Datum
concat_text(PG_FUNCTION_ARGS)
{
    text  *arg1 = PG_GETARG_TEXT_P(0);
    text  *arg2 = PG_GETARG_TEXT_P(1);
    int32 new_text_size = VARSIZE(arg1) + VARSIZE(arg2) - VARHDRSZ;
    text *new_text = (text *) palloc(new_text_size);

    SET_VARSIZE(new_text, new_text_size);
    memcpy(VARDATA(new_text), VARDATA(arg1), VARSIZE(arg1) - VARHDRSZ);
    memcpy(VARDATA(new_text) + (VARSIZE(arg1) - VARHDRSZ),
           VARDATA(arg2), VARSIZE(arg2) - VARHDRSZ);
    PG_RETURN_TEXT_P(new_text);
}
```

The `CREATE FUNCTION` commands are the same as for the version-0 equivalents.

At first glance, the version-1 coding conventions might appear to be just pointless obscurantism. They do, however, offer a number of improvements, because the macros can hide unnecessary detail. An example is that in coding `add_one_float8`, we no longer need to be aware that `float8` is a pass-by-reference type. Another example is that the `GETARG` macros for variable-length types allow for more efficient fetching of "toasted" (compressed or out-of-line) values.

One big improvement in version-1 functions is better handling of null inputs and results. The macro `PG_ARGISNULL(`*n*`)` allows a function to test whether each input is null. (Of course, doing this is

only necessary in functions not declared "strict".) As with the PG_GETARG_*xxx*() macros, the input arguments are counted beginning at zero. Note that one should refrain from executing PG_GETARG_*xxx*() until one has verified that the argument isn't null. To return a null result, execute PG_RETURN_NULL(); this works in both strict and nonstrict functions.

Other options provided in the new-style interface are two variants of the PG_GETARG_*xxx*() macros. The first of these, PG_GETARG_*xxx*_COPY(), guarantees to return a copy of the specified argument that is safe for writing into. (The normal macros will sometimes return a pointer to a value that is physically stored in a table, which must not be written to. Using the PG_GETARG_*xxx*_COPY() macros guarantees a writable result.) The second variant consists of the PG_GETARG_*xxx*_SLICE() macros which take three arguments. The first is the number of the function argument (as above). The second and third are the offset and length of the segment to be returned. Offsets are counted from zero, and a negative length requests that the remainder of the value be returned. These macros provide more efficient access to parts of large values in the case where they have storage type "external". (The storage type of a column can be specified using ALTER TABLE *tablename* ALTER COLUMN *colname* SET STORAGE *storagetype*. *storagetype* is one of plain, external, extended, or main.)

Finally, the version-1 function call conventions make it possible to return set results (Section 35.9.9) and implement trigger functions (Chapter 36) and procedural-language call handlers (Chapter 52). Version-1 code is also more portable than version-0, because it does not break restrictions on function call protocol in the C standard. For more details see src/backend/utils/fmgr/README in the source distribution.

35.9.5. Writing Code

Before we turn to the more advanced topics, we should discuss some coding rules for PostgreSQL C-language functions. While it might be possible to load functions written in languages other than C into PostgreSQL, this is usually difficult (when it is possible at all) because other languages, such as C++, FORTRAN, or Pascal often do not follow the same calling convention as C. That is, other languages do not pass argument and return values between functions in the same way. For this reason, we will assume that your C-language functions are actually written in C.

The basic rules for writing and building C functions are as follows:

- Use pg_config --includedir-server to find out where the PostgreSQL server header files are installed on your system (or the system that your users will be running on).
- Compiling and linking your code so that it can be dynamically loaded into PostgreSQL always requires special flags. See Section 35.9.6 for a detailed explanation of how to do it for your particular operating system.
- Remember to define a "magic block" for your shared library, as described in Section 35.9.1.
- When allocating memory, use the PostgreSQL functions palloc and pfree instead of the corresponding C library functions malloc and free. The memory allocated by palloc will be freed automatically at the end of each transaction, preventing memory leaks.
- Always zero the bytes of your structures using memset (or allocate them with palloc0 in the first place). Even if you assign to each field of your structure, there might be alignment padding (holes in the structure) that contain garbage values. Without this, it's difficult to support hash indexes or hash joins, as you must pick out only the significant bits of your data structure to compute a hash. The planner also sometimes relies on comparing constants via bitwise equality, so you can get undesirable planning results if logically-equivalent values aren't bitwise equal.

- Most of the internal PostgreSQL types are declared in `postgres.h`, while the function manager interfaces (`PG_FUNCTION_ARGS`, etc.) are in `fmgr.h`, so you will need to include at least these two files. For portability reasons it's best to include `postgres.h` *first*, before any other system or user header files. Including `postgres.h` will also include `elog.h` and `palloc.h` for you.
- Symbol names defined within object files must not conflict with each other or with symbols defined in the PostgreSQL server executable. You will have to rename your functions or variables if you get error messages to this effect.

35.9.6. Compiling and Linking Dynamically-loaded Functions

Before you are able to use your PostgreSQL extension functions written in C, they must be compiled and linked in a special way to produce a file that can be dynamically loaded by the server. To be precise, a *shared library* needs to be created.

For information beyond what is contained in this section you should read the documentation of your operating system, in particular the manual pages for the C compiler, `cc`, and the link editor, `ld`. In addition, the PostgreSQL source code contains several working examples in the `contrib` directory. If you rely on these examples you will make your modules dependent on the availability of the PostgreSQL source code, however.

Creating shared libraries is generally analogous to linking executables: first the source files are compiled into object files, then the object files are linked together. The object files need to be created as *position-independent code* (PIC), which conceptually means that they can be placed at an arbitrary location in memory when they are loaded by the executable. (Object files intended for executables are usually not compiled that way.) The command to link a shared library contains special flags to distinguish it from linking an executable (at least in theory — on some systems the practice is much uglier).

In the following examples we assume that your source code is in a file `foo.c` and we will create a shared library `foo.so`. The intermediate object file will be called `foo.o` unless otherwise noted. A shared library can contain more than one object file, but we only use one here.

FreeBSD

The compiler flag to create PIC is `-fpic`. To create shared libraries the compiler flag is `-shared`.

```
gcc -fpic -c foo.c
gcc -shared -o foo.so foo.o
```

This is applicable as of version 3.0 of FreeBSD.

HP-UX

The compiler flag of the system compiler to create PIC is `+z`. When using GCC it's `-fpic`. The linker flag for shared libraries is `-b`. So:

```
cc +z -c foo.c
```

or:

```
gcc -fpic -c foo.c
```

and then:

```
ld -b -o foo.sl foo.o
```

HP-UX uses the extension `.sl` for shared libraries, unlike most other systems.

Linux

The compiler flag to create PIC is `-fpic`. On some platforms in some situations `-fPIC` must be used if `-fpic` does not work. Refer to the GCC manual for more information. The compiler flag to create a shared library is `-shared`. A complete example looks like this:

```
cc -fpic -c foo.c
cc -shared -o foo.so foo.o
```

OS X

Here is an example. It assumes the developer tools are installed.

```
cc -c foo.c
cc -bundle -flat_namespace -undefined suppress -o foo.so foo.o
```

NetBSD

The compiler flag to create PIC is `-fpic`. For ELF systems, the compiler with the flag `-shared` is used to link shared libraries. On the older non-ELF systems, `ld -Bshareable` is used.

```
gcc -fpic -c foo.c
gcc -shared -o foo.so foo.o
```

OpenBSD

The compiler flag to create PIC is `-fpic`. `ld -Bshareable` is used to link shared libraries.

```
gcc -fpic -c foo.c
ld -Bshareable -o foo.so foo.o
```

Solaris

The compiler flag to create PIC is `-KPIC` with the Sun compiler and `-fpic` with GCC. To link shared libraries, the compiler option is `-G` with either compiler or alternatively `-shared` with GCC.

```
cc -KPIC -c foo.c
cc -G -o foo.so foo.o
```

or

```
gcc -fpic -c foo.c
gcc -G -o foo.so foo.o
```

Tru64 UNIX

PIC is the default, so the compilation command is the usual one. `ld` with special options is used to do the linking.

```
cc -c foo.c
ld -shared -expect_unresolved '*' -o foo.so foo.o
```

The same procedure is used with GCC instead of the system compiler; no special options are required.

UnixWare

The compiler flag to create PIC is `-K PIC` with the SCO compiler and `-fpic` with GCC. To link shared libraries, the compiler option is `-G` with the SCO compiler and `-shared` with GCC.

```
cc -K PIC -c foo.c
cc -G -o foo.so foo.o
```

or

```
gcc -fpic -c foo.c
gcc -shared -o foo.so foo.o
```

Tip: If this is too complicated for you, you should consider using GNU Libtool[1], which hides the platform differences behind a uniform interface.

The resulting shared library file can then be loaded into PostgreSQL. When specifying the file name to the `CREATE FUNCTION` command, one must give it the name of the shared library file, not the intermediate object file. Note that the system's standard shared-library extension (usually `.so` or `.sl`) can be omitted from the `CREATE FUNCTION` command, and normally should be omitted for best portability.

Refer back to Section 35.9.1 about where the server expects to find the shared library files.

35.9.7. Composite-type Arguments

Composite types do not have a fixed layout like C structures. Instances of a composite type can contain null fields. In addition, composite types that are part of an inheritance hierarchy can have different fields than other members of the same inheritance hierarchy. Therefore, PostgreSQL provides a function interface for accessing fields of composite types from C.

Suppose we want to write a function to answer the query:

```
SELECT name, c_overpaid(emp, 1500) AS overpaid
    FROM emp
    WHERE name = 'Bill' OR name = 'Sam';
```

Using call conventions version 0, we can define `c_overpaid` as:

```
#include "postgres.h"
#include "executor/executor.h"  /* for GetAttributeByName() */

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif

bool
c_overpaid(HeapTupleHeader t, /* the current row of emp */
           int32 limit)
{
    bool isnull;
    int32 salary;

    salary = DatumGetInt32(GetAttributeByName(t, "salary", &isnull));
    if (isnull)
        return false;
    return salary > limit;
}
```

In version-1 coding, the above would look like this:

```
#include "postgres.h"
#include "executor/executor.h"  /* for GetAttributeByName() */

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
```

1. http://www.gnu.org/software/libtool/

```
#endif

PG_FUNCTION_INFO_V1(c_overpaid);

Datum
c_overpaid(PG_FUNCTION_ARGS)
{
    HeapTupleHeader  t = PG_GETARG_HEAPTUPLEHEADER(0);
    int32            limit = PG_GETARG_INT32(1);
    bool isnull;
    Datum salary;

    salary = GetAttributeByName(t, "salary", &isnull);
    if (isnull)
        PG_RETURN_BOOL(false);
    /* Alternatively, we might prefer to do PG_RETURN_NULL() for null salary. */

    PG_RETURN_BOOL(DatumGetInt32(salary) > limit);
}
```

`GetAttributeByName` is the PostgreSQL system function that returns attributes out of the specified row. It has three arguments: the argument of type `HeapTupleHeader` passed into the function, the name of the desired attribute, and a return parameter that tells whether the attribute is null. `GetAttributeByName` returns a `Datum` value that you can convert to the proper data type by using the appropriate `DatumGet`*`XXX`*`()` macro. Note that the return value is meaningless if the null flag is set; always check the null flag before trying to do anything with the result.

There is also `GetAttributeByNum`, which selects the target attribute by column number instead of name.

The following command declares the function `c_overpaid` in SQL:

```
CREATE FUNCTION c_overpaid(emp, integer) RETURNS boolean
    AS 'DIRECTORY/funcs', 'c_overpaid'
    LANGUAGE C STRICT;
```

Notice we have used `STRICT` so that we did not have to check whether the input arguments were NULL.

35.9.8. Returning Rows (Composite Types)

To return a row or composite-type value from a C-language function, you can use a special API that provides macros and functions to hide most of the complexity of building composite data types. To use this API, the source file must include:

```
#include "funcapi.h"
```

There are two ways you can build a composite data value (henceforth a "tuple"): you can build it from an array of Datum values, or from an array of C strings that can be passed to the input conversion functions of the tuple's column data types. In either case, you first need to obtain or construct a `TupleDesc` descriptor for the tuple structure. When working with Datums, you pass the

TupleDesc to BlessTupleDesc, and then call heap_form_tuple for each row. When working with C strings, you pass the TupleDesc to TupleDescGetAttInMetadata, and then call BuildTupleFromCStrings for each row. In the case of a function returning a set of tuples, the setup steps can all be done once during the first call of the function.

Several helper functions are available for setting up the needed TupleDesc. The recommended way to do this in most functions returning composite values is to call:

```
TypeFuncClass get_call_result_type(FunctionCallInfo fcinfo,
                                   Oid *resultTypeId,
                                   TupleDesc *resultTupleDesc)
```

passing the same fcinfo struct passed to the calling function itself. (This of course requires that you use the version-1 calling conventions.) resultTypeId can be specified as NULL or as the address of a local variable to receive the function's result type OID. resultTupleDesc should be the address of a local TupleDesc variable. Check that the result is TYPEFUNC_COMPOSITE; if so, resultTupleDesc has been filled with the needed TupleDesc. (If it is not, you can report an error along the lines of "function returning record called in context that cannot accept type record".)

> **Tip:** get_call_result_type can resolve the actual type of a polymorphic function result; so it is useful in functions that return scalar polymorphic results, not only functions that return composites. The resultTypeId output is primarily useful for functions returning polymorphic scalars.

> **Note:** get_call_result_type has a sibling get_expr_result_type, which can be used to resolve the expected output type for a function call represented by an expression tree. This can be used when trying to determine the result type from outside the function itself. There is also get_func_result_type, which can be used when only the function's OID is available. However these functions are not able to deal with functions declared to return record, and get_func_result_type cannot resolve polymorphic types, so you should preferentially use get_call_result_type.

Older, now-deprecated functions for obtaining TupleDescs are:

```
TupleDesc RelationNameGetTupleDesc(const char *relname)
```

to get a TupleDesc for the row type of a named relation, and:

```
TupleDesc TypeGetTupleDesc(Oid typeoid, List *colaliases)
```

to get a TupleDesc based on a type OID. This can be used to get a TupleDesc for a base or composite type. It will not work for a function that returns record, however, and it cannot resolve polymorphic types.

Once you have a TupleDesc, call:

```
TupleDesc BlessTupleDesc(TupleDesc tupdesc)
```

if you plan to work with Datums, or:

```
AttInMetadata *TupleDescGetAttInMetadata(TupleDesc tupdesc)
```

if you plan to work with C strings. If you are writing a function returning set, you can save the results of these functions in the FuncCallContext structure — use the tuple_desc or attinmeta field respectively.

When working with Datums, use:

```
HeapTuple heap_form_tuple(TupleDesc tupdesc, Datum *values, bool *isnull)
```

to build a `HeapTuple` given user data in Datum form.

When working with C strings, use:

```
HeapTuple BuildTupleFromCStrings(AttInMetadata *attinmeta, char **values)
```

to build a `HeapTuple` given user data in C string form. `values` is an array of C strings, one for each attribute of the return row. Each C string should be in the form expected by the input function of the attribute data type. In order to return a null value for one of the attributes, the corresponding pointer in the `values` array should be set to `NULL`. This function will need to be called again for each row you return.

Once you have built a tuple to return from your function, it must be converted into a `Datum`. Use:

```
HeapTupleGetDatum(HeapTuple tuple)
```

to convert a `HeapTuple` into a valid Datum. This `Datum` can be returned directly if you intend to return just a single row, or it can be used as the current return value in a set-returning function.

An example appears in the next section.

35.9.9. Returning Sets

There is also a special API that provides support for returning sets (multiple rows) from a C-language function. A set-returning function must follow the version-1 calling conventions. Also, source files must include `funcapi.h`, as above.

A set-returning function (SRF) is called once for each item it returns. The SRF must therefore save enough state to remember what it was doing and return the next item on each call. The structure `FuncCallContext` is provided to help control this process. Within a function, `fcinfo->flinfo->fn_extra` is used to hold a pointer to `FuncCallContext` across calls.

```
typedef struct
{
    /*
     * Number of times we've been called before
     *
     * call_cntr is initialized to 0 for you by SRF_FIRSTCALL_INIT(), and
     * incremented for you every time SRF_RETURN_NEXT() is called.
     */
    uint32 call_cntr;

    /*
     * OPTIONAL maximum number of calls
     *
     * max_calls is here for convenience only and setting it is optional.
     * If not set, you must provide alternative means to know when the
     * function is done.
     */
    uint32 max_calls;

    /*
     * OPTIONAL pointer to result slot
```

```
     *
     * This is obsolete and only present for backward compatibility, viz,
     * user-defined SRFs that use the deprecated TupleDescGetSlot().
     */
    TupleTableSlot *slot;

    /*
     * OPTIONAL pointer to miscellaneous user-provided context information
     *
     * user_fctx is for use as a pointer to your own data to retain
     * arbitrary context information between calls of your function.
     */
    void *user_fctx;

    /*
     * OPTIONAL pointer to struct containing attribute type input metadata
     *
     * attinmeta is for use when returning tuples (i.e., composite data types)
     * and is not used when returning base data types. It is only needed
     * if you intend to use BuildTupleFromCStrings() to create the return
     * tuple.
     */
    AttInMetadata *attinmeta;

    /*
     * memory context used for structures that must live for multiple calls
     *
     * multi_call_memory_ctx is set by SRF_FIRSTCALL_INIT() for you, and used
     * by SRF_RETURN_DONE() for cleanup. It is the most appropriate memory
     * context for any memory that is to be reused across multiple calls
     * of the SRF.
     */
    MemoryContext multi_call_memory_ctx;

    /*
     * OPTIONAL pointer to struct containing tuple description
     *
     * tuple_desc is for use when returning tuples (i.e., composite data types)
     * and is only needed if you are going to build the tuples with
     * heap_form_tuple() rather than with BuildTupleFromCStrings().  Note that
     * the TupleDesc pointer stored here should usually have been run through
     * BlessTupleDesc() first.
     */
    TupleDesc tuple_desc;

} FuncCallContext;
```

An SRF uses several functions and macros that automatically manipulate the `FuncCallContext` structure (and expect to find it via `fn_extra`). Use:

```
SRF_IS_FIRSTCALL()
```

to determine if your function is being called for the first or a subsequent time. On the first call (only) use:

```
SRF_FIRSTCALL_INIT()
```

to initialize the FuncCallContext. On every function call, including the first, use:

```
SRF_PERCALL_SETUP()
```

to properly set up for using the FuncCallContext and clearing any previously returned data left over from the previous pass.

If your function has data to return, use:

```
SRF_RETURN_NEXT(funcctx, result)
```

to return it to the caller. (result must be of type Datum, either a single value or a tuple prepared as described above.) Finally, when your function is finished returning data, use:

```
SRF_RETURN_DONE(funcctx)
```

to clean up and end the SRF.

The memory context that is current when the SRF is called is a transient context that will be cleared between calls. This means that you do not need to call pfree on everything you allocated using palloc; it will go away anyway. However, if you want to allocate any data structures to live across calls, you need to put them somewhere else. The memory context referenced by multi_call_memory_ctx is a suitable location for any data that needs to survive until the SRF is finished running. In most cases, this means that you should switch into multi_call_memory_ctx while doing the first-call setup.

A complete pseudo-code example looks like the following:

```
Datum
my_set_returning_function(PG_FUNCTION_ARGS)
{
    FuncCallContext  *funcctx;
    Datum             result;
    further declarations as needed

    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext oldcontext;

        funcctx = SRF_FIRSTCALL_INIT();
        oldcontext = MemoryContextSwitchTo(funcctx->multi_call_memory_ctx);
        /* One-time setup code appears here: */
        user code
        if returning composite
            build TupleDesc, and perhaps AttInMetadata
        endif returning composite
        user code
        MemoryContextSwitchTo(oldcontext);
    }

    /* Each-time setup code appears here: */
    user code
    funcctx = SRF_PERCALL_SETUP();
    user code

    /* this is just one way we might test whether we are done: */
    if (funcctx->call_cntr < funcctx->max_calls)
    {
        /* Here we want to return another item: */
        user code
```

```
        obtain result Datum
        SRF_RETURN_NEXT(funcctx, result);
    }
    else
    {
        /* Here we are done returning items and just need to clean up: */
        user code
        SRF_RETURN_DONE(funcctx);
    }
}
```

A complete example of a simple SRF returning a composite type looks like:

```
PG_FUNCTION_INFO_V1(retcomposite);

Datum
retcomposite(PG_FUNCTION_ARGS)
{
    FuncCallContext     *funcctx;
    int                  call_cntr;
    int                  max_calls;
    TupleDesc            tupdesc;
    AttInMetadata       *attinmeta;

    /* stuff done only on the first call of the function */
    if (SRF_IS_FIRSTCALL())
    {
        MemoryContext   oldcontext;

        /* create a function context for cross-call persistence */
        funcctx = SRF_FIRSTCALL_INIT();

        /* switch to memory context appropriate for multiple function calls */
        oldcontext = MemoryContextSwitchTo(funcctx->multi_call_memory_ctx);

        /* total number of tuples to be returned */
        funcctx->max_calls = PG_GETARG_UINT32(0);

        /* Build a tuple descriptor for our result type */
        if (get_call_result_type(fcinfo, NULL, &tupdesc) != TYPEFUNC_COMPOSITE)
            ereport(ERROR,
                    (errcode(ERRCODE_FEATURE_NOT_SUPPORTED),
                     errmsg("function returning record called in context "
                            "that cannot accept type record")));

        /*
         * generate attribute metadata needed later to produce tuples from raw
         * C strings
         */
        attinmeta = TupleDescGetAttInMetadata(tupdesc);
        funcctx->attinmeta = attinmeta;

        MemoryContextSwitchTo(oldcontext);
    }

    /* stuff done on every call of the function */
```

```
    funcctx = SRF_PERCALL_SETUP();

    call_cntr = funcctx->call_cntr;
    max_calls = funcctx->max_calls;
    attinmeta = funcctx->attinmeta;

    if (call_cntr < max_calls)    /* do when there is more left to send */
    {
        char       **values;
        HeapTuple    tuple;
        Datum        result;

        /*
         * Prepare a values array for building the returned tuple.
         * This should be an array of C strings which will
         * be processed later by the type input functions.
         */
        values = (char **) palloc(3 * sizeof(char *));
        values[0] = (char *) palloc(16 * sizeof(char));
        values[1] = (char *) palloc(16 * sizeof(char));
        values[2] = (char *) palloc(16 * sizeof(char));

        snprintf(values[0], 16, "%d", 1 * PG_GETARG_INT32(1));
        snprintf(values[1], 16, "%d", 2 * PG_GETARG_INT32(1));
        snprintf(values[2], 16, "%d", 3 * PG_GETARG_INT32(1));

        /* build a tuple */
        tuple = BuildTupleFromCStrings(attinmeta, values);

        /* make the tuple into a datum */
        result = HeapTupleGetDatum(tuple);

        /* clean up (this is not really necessary) */
        pfree(values[0]);
        pfree(values[1]);
        pfree(values[2]);
        pfree(values);

        SRF_RETURN_NEXT(funcctx, result);
    }
    else    /* do when there is no more left */
    {
        SRF_RETURN_DONE(funcctx);
    }
}
```

One way to declare this function in SQL is:

```
CREATE TYPE __retcomposite AS (f1 integer, f2 integer, f3 integer);

CREATE OR REPLACE FUNCTION retcomposite(integer, integer)
    RETURNS SETOF __retcomposite
    AS 'filename', 'retcomposite'
    LANGUAGE C IMMUTABLE STRICT;
```

A different way is to use OUT parameters:

```
CREATE OR REPLACE FUNCTION retcomposite(IN integer, IN integer,
```

```
    OUT f1 integer, OUT f2 integer, OUT f3 integer)
    RETURNS SETOF record
    AS 'filename', 'retcomposite'
    LANGUAGE C IMMUTABLE STRICT;
```

Notice that in this method the output type of the function is formally an anonymous `record` type.

The directory contrib/tablefunc module in the source distribution contains more examples of set-returning functions.

35.9.10. Polymorphic Arguments and Return Types

C-language functions can be declared to accept and return the polymorphic types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`. See Section 35.2.5 for a more detailed explanation of polymorphic functions. When function arguments or return types are defined as polymorphic types, the function author cannot know in advance what data type it will be called with, or need to return. There are two routines provided in `fmgr.h` to allow a version-1 C function to discover the actual data types of its arguments and the type it is expected to return. The routines are called `get_fn_expr_rettype(FmgrInfo *flinfo)` and `get_fn_expr_argtype(FmgrInfo *flinfo, int argnum)`. They return the result or argument type OID, or `InvalidOid` if the information is not available. The structure `flinfo` is normally accessed as `fcinfo->flinfo`. The parameter `argnum` is zero based. `get_call_result_type` can also be used as an alternative to `get_fn_expr_rettype`. There is also `get_fn_expr_variadic`, which can be used to find out whether variadic arguments have been merged into an array. This is primarily useful for `VARIADIC "any"` functions, since such merging will always have occurred for variadic functions taking ordinary array types.

For example, suppose we want to write a function to accept a single element of any type, and return a one-dimensional array of that type:

```
PG_FUNCTION_INFO_V1(make_array);
Datum
make_array(PG_FUNCTION_ARGS)
{
    ArrayType  *result;
    Oid         element_type = get_fn_expr_argtype(fcinfo->flinfo, 0);
    Datum       element;
    bool        isnull;
    int16       typlen;
    bool        typbyval;
    char        typalign;
    int         ndims;
    int         dims[MAXDIM];
    int         lbs[MAXDIM];

    if (!OidIsValid(element_type))
        elog(ERROR, "could not determine data type of input");

    /* get the provided element, being careful in case it's NULL */
    isnull = PG_ARGISNULL(0);
    if (isnull)
        element = (Datum) 0;
    else
        element = PG_GETARG_DATUM(0);
```

```
    /* we have one dimension */
    ndims = 1;
    /* and one element */
    dims[0] = 1;
    /* and lower bound is 1 */
    lbs[0] = 1;

    /* get required info about the element type */
    get_typlenbyvalalign(element_type, &typlen, &typbyval, &typalign);

    /* now build the array */
    result = construct_md_array(&element, &isnull, ndims, dims, lbs,
                                element_type, typlen, typbyval, typalign);

    PG_RETURN_ARRAYTYPE_P(result);
}
```

The following command declares the function `make_array` in SQL:

```
CREATE FUNCTION make_array(anyelement) RETURNS anyarray
    AS 'DIRECTORY/funcs', 'make_array'
    LANGUAGE C IMMUTABLE;
```

There is a variant of polymorphism that is only available to C-language functions: they can be declared to take parameters of type `"any"`. (Note that this type name must be double-quoted, since it's also a SQL reserved word.) This works like `anyelement` except that it does not constrain different `"any"` arguments to be the same type, nor do they help determine the function's result type. A C-language function can also declare its final parameter to be `VARIADIC "any"`. This will match one or more actual arguments of any type (not necessarily the same type). These arguments will *not* be gathered into an array as happens with normal variadic functions; they will just be passed to the function separately. The `PG_NARGS()` macro and the methods described above must be used to determine the number of actual arguments and their types when using this feature. Also, users of such a function might wish to use the `VARIADIC` keyword in their function call, with the expectation that the function would treat the array elements as separate arguments. The function itself must implement that behavior if wanted, after using `get_fn_expr_variadic` to detect that the actual argument was marked with `VARIADIC`.

35.9.11. Transform Functions

Some function calls can be simplified during planning based on properties specific to the function. For example, `int4mul(n, 1)` could be simplified to just `n`. To define such function-specific optimizations, write a *transform function* and place its OID in the `protransform` field of the primary function's `pg_proc` entry. The transform function must have the SQL signature `protransform(internal) RETURNS internal`. The argument, actually `FuncExpr *`, is a dummy node representing a call to the primary function. If the transform function's study of the expression tree proves that a simplified expression tree can substitute for all possible concrete calls represented thereby, build and return that simplified expression. Otherwise, return a `NULL` pointer (*not* a SQL null).

We make no guarantee that PostgreSQL will never call the primary function in cases that the transform function could simplify. Ensure rigorous equivalence between the simplified expression and an actual call to the primary function.

Currently, this facility is not exposed to users at the SQL level because of security concerns, so it is only practical to use for optimizing built-in functions.

35.9.12. Shared Memory and LWLocks

Add-ins can reserve LWLocks and an allocation of shared memory on server startup. The add-in's shared library must be preloaded by specifying it in shared_preload_libraries. Shared memory is reserved by calling:

```
void RequestAddinShmemSpace(int size)
```

from your `_PG_init` function.

LWLocks are reserved by calling:

```
void RequestAddinLWLocks(int n)
```

from `_PG_init`.

To avoid possible race-conditions, each backend should use the LWLock `AddinShmemInitLock` when connecting to and initializing its allocation of shared memory, as shown here:

```
static mystruct *ptr = NULL;

if (!ptr)
{
        bool    found;

        LWLockAcquire(AddinShmemInitLock, LW_EXCLUSIVE);
        ptr = ShmemInitStruct("my struct name", size, &found);
        if (!found)
        {
                initialize contents of shmem area;
                acquire any requested LWLocks using:
                ptr->mylockid = LWLockAssign();
        }
        LWLockRelease(AddinShmemInitLock);
}
```

35.9.13. Using C++ for Extensibility

Although the PostgreSQL backend is written in C, it is possible to write extensions in C++ if these guidelines are followed:

- All functions accessed by the backend must present a C interface to the backend; these C functions can then call C++ functions. For example, `extern C` linkage is required for backend-accessed functions. This is also necessary for any functions that are passed as pointers between the backend and C++ code.
- Free memory using the appropriate deallocation method. For example, most backend memory is allocated using `palloc()`, so use `pfree()` to free it. Using C++ `delete` in such cases will fail.

- Prevent exceptions from propagating into the C code (use a catch-all block at the top level of all `extern C` functions). This is necessary even if the C++ code does not explicitly throw any exceptions, because events like out-of-memory can still throw exceptions. Any exceptions must be caught and appropriate errors passed back to the C interface. If possible, compile C++ with `-fno-exceptions` to eliminate exceptions entirely; in such cases, you must check for failures in your C++ code, e.g. check for NULL returned by `new()`.
- If calling backend functions from C++ code, be sure that the C++ call stack contains only plain old data structures (POD). This is necessary because backend errors generate a distant `longjmp()` that does not properly unroll a C++ call stack with non-POD objects.

In summary, it is best to place C++ code behind a wall of `extern C` functions that interface to the backend, and avoid exception, memory, and call stack leakage.

35.10. User-defined Aggregates

Aggregate functions in PostgreSQL are defined in terms of *state values* and *state transition functions*. That is, an aggregate operates using a state value that is updated as each successive input row is processed. To define a new aggregate function, one selects a data type for the state value, an initial value for the state, and a state transition function. The state transition function takes the previous state value and the aggregate's input value(s) for the current row, and returns a new state value. A *final function* can also be specified, in case the desired result of the aggregate is different from the data that needs to be kept in the running state value. The final function takes the last state value and returns whatever is wanted as the aggregate result. In principle, the transition and final functions are just ordinary functions that could also be used outside the context of the aggregate. (In practice, it's often helpful for performance reasons to create specialized transition functions that can only work when called as part of an aggregate.)

Thus, in addition to the argument and result data types seen by a user of the aggregate, there is an internal state-value data type that might be different from both the argument and result types.

If we define an aggregate that does not use a final function, we have an aggregate that computes a running function of the column values from each row. `sum` is an example of this kind of aggregate. `sum` starts at zero and always adds the current row's value to its running total. For example, if we want to make a `sum` aggregate to work on a data type for complex numbers, we only need the addition function for that data type. The aggregate definition would be:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)'
);
```

which we might use like this:

```
SELECT sum(a) FROM test_complex;

   sum
-----------
 (34,53.9)
```

(Notice that we are relying on function overloading: there is more than one aggregate named `sum`, but PostgreSQL can figure out which kind of sum applies to a column of type `complex`.)

The above definition of `sum` will return zero (the initial state value) if there are no nonnull input values. Perhaps we want to return null in that case instead — the SQL standard expects `sum` to behave that way. We can do this simply by omitting the `initcond` phrase, so that the initial state value is null. Ordinarily this would mean that the `sfunc` would need to check for a null state-value input. But for `sum` and some other simple aggregates like `max` and `min`, it is sufficient to insert the first nonnull input value into the state variable and then start applying the transition function at the second nonnull input value. PostgreSQL will do that automatically if the initial state value is null and the transition function is marked "strict" (i.e., not to be called for null inputs).

Another bit of default behavior for a "strict" transition function is that the previous state value is retained unchanged whenever a null input value is encountered. Thus, null values are ignored. If you need some other behavior for null inputs, do not declare your transition function as strict; instead code it to test for null inputs and do whatever is needed.

`avg` (average) is a more complex example of an aggregate. It requires two pieces of running state: the sum of the inputs and the count of the number of inputs. The final result is obtained by dividing these quantities. Average is typically implemented by using an array as the state value. For example, the built-in implementation of `avg(float8)` looks like:

```
CREATE AGGREGATE avg (float8)
(
    sfunc = float8_accum,
    stype = float8[],
    finalfunc = float8_avg,
    initcond = '{0,0,0}'
);
```

> **Note:** `float8_accum` requires a three-element array, not just two elements, because it accumulates the sum of squares as well as the sum and count of the inputs. This is so that it can be used for some other aggregates as well as `avg`.

Aggregate function calls in SQL allow `DISTINCT` and `ORDER BY` options that control which rows are fed to the aggregate's transition function and in what order. These options are implemented behind the scenes and are not the concern of the aggregate's support functions.

For further details see the CREATE AGGREGATE command.

35.10.1. Moving-Aggregate Mode

Aggregate functions can optionally support *moving-aggregate mode*, which allows substantially faster execution of aggregate functions within windows with moving frame starting points. (See Section 3.5 and Section 4.2.8 for information about use of aggregate functions as window functions.) The basic idea is that in addition to a normal "forward" transition function, the aggregate provides an *inverse transition function*, which allows rows to be removed from the aggregate's running state value when they exit the window frame. For example a `sum` aggregate, which uses addition as the forward transition function, would use subtraction as the inverse transition function. Without an inverse transition function, the window function mechanism must recalculate the aggregate from scratch each time the frame starting point moves, resulting in run time proportional to the number of input rows times the

average frame length. With an inverse transition function, the run time is only proportional to the number of input rows.

The inverse transition function is passed the current state value and the aggregate input value(s) for the earliest row included in the current state. It must reconstruct what the state value would have been if the given input row had never been aggregated, but only the rows following it. This sometimes requires that the forward transition function keep more state than is needed for plain aggregation mode. Therefore, the moving-aggregate mode uses a completely separate implementation from the plain mode: it has its own state data type, its own forward transition function, and its own final function if needed. These can be the same as the plain mode's data type and functions, if there is no need for extra state.

As an example, we could extend the `sum` aggregate given above to support moving-aggregate mode like this:

```
CREATE AGGREGATE sum (complex)
(
    sfunc = complex_add,
    stype = complex,
    initcond = '(0,0)',
    msfunc = complex_add,
    minvfunc = complex_sub,
    mstype = complex,
    minitcond = '(0,0)'
);
```

The parameters whose names begin with `m` define the moving-aggregate implementation. Except for the inverse transition function `minvfunc`, they correspond to the plain-aggregate parameters without `m`.

The forward transition function for moving-aggregate mode is not allowed to return null as the new state value. If the inverse transition function returns null, this is taken as an indication that the inverse function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value. The inverse transition function can "punt" on these cases, and yet still come out ahead so long as it can work for most cases. As an example, an aggregate working with floating-point numbers might choose to punt when a `NaN` (not a number) input has to be removed from the running state value.

When writing moving-aggregate support functions, it is important to be sure that the inverse transition function can reconstruct the correct state value exactly. Otherwise there might be user-visible differences in results depending on whether the moving-aggregate mode is used. An example of an aggregate for which adding an inverse transition function seems easy at first, yet where this requirement cannot be met is `sum` over `float4` or `float8` inputs. A naive declaration of `sum(float8)` could be

```
CREATE AGGREGATE unsafe_sum (float8)
(
    stype = float8,
    sfunc = float8pl,
    mstype = float8,
    msfunc = float8pl,
    minvfunc = float8mi
);
```

This aggregate, however, can give wildly different results than it would have without the inverse transition function. For example, consider

```
SELECT
  unsafe_sum(x) OVER (ORDER BY n ROWS BETWEEN CURRENT ROW AND 1 FOLLOWING)
FROM (VALUES (1, 1.0e20::float8),
             (2, 1.0::float8)) AS v (n,x);
```

This query returns `0` as its second result, rather than the expected answer of `1`. The cause is the limited precision of floating-point values: adding `1` to `1e20` results in `1e20` again, and so subtracting `1e20` from that yields `0`, not `1`. Note that this is a limitation of floating-point arithmetic in general, not a limitation of PostgreSQL.

35.10.2. Polymorphic and Variadic Aggregates

Aggregate functions can use polymorphic state transition functions or final functions, so that the same functions can be used to implement multiple aggregates. See Section 35.2.5 for an explanation of polymorphic functions. Going a step further, the aggregate function itself can be specified with polymorphic input type(s) and state type, allowing a single aggregate definition to serve for multiple input data types. Here is an example of a polymorphic aggregate:

```
CREATE AGGREGATE array_accum (anyelement)
(
    sfunc = array_append,
    stype = anyarray,
    initcond = '{}'
);
```

Here, the actual state type for any given aggregate call is the array type having the actual input type as elements. The behavior of the aggregate is to concatenate all the inputs into an array of that type. (Note: the built-in aggregate `array_agg` provides similar functionality, with better performance than this definition would have.)

Here's the output using two different actual data types as arguments:

```
SELECT attrelid::regclass, array_accum(attname)
    FROM pg_attribute
    WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
    GROUP BY attrelid;

   attrelid    |              array_accum
---------------+---------------------------------------
 pg_tablespace | {spcname,spcowner,spcacl,spcoptions}
(1 row)

SELECT attrelid::regclass, array_accum(atttypid::regtype)
    FROM pg_attribute
    WHERE attnum > 0 AND attrelid = 'pg_tablespace'::regclass
    GROUP BY attrelid;

   attrelid    |        array_accum
---------------+---------------------------
 pg_tablespace | {name,oid,aclitem[],text[]}
(1 row)
```

Ordinarily, an aggregate function with a polymorphic result type has a polymorphic state type, as in the above example. This is necessary because otherwise the final function cannot be declared sensibly: it would need to have a polymorphic result type but no polymorphic argument type, which `CREATE FUNCTION` will reject on the grounds that the result type cannot be deduced from a call. But sometimes it is inconvenient to use a polymorphic state type. The most common case is where the aggregate support functions are to be written in C and the state type should be declared as `internal` because there is no SQL-level equivalent for it. To address this case, it is possible to declare the final function as taking extra "dummy" arguments that match the input arguments of the aggregate. Such dummy arguments are always passed as null values since no specific value is available when the final function is called. Their only use is to allow a polymorphic final function's result type to be connected to the aggregate's input type(s). For example, the definition of the built-in aggregate `array_agg` is equivalent to

```
CREATE FUNCTION array_agg_transfn(internal, anyelement)
  RETURNS internal ...;
CREATE FUNCTION array_agg_finalfn(internal, anyelement)
  RETURNS anyarray ...;

CREATE AGGREGATE array_agg (anyelement)
(
    sfunc = array_agg_transfn,
    stype = internal,
    finalfunc = array_agg_finalfn,
    finalfunc_extra
);
```

Here, the `finalfunc_extra` option specifies that the final function receives, in addition to the state value, extra dummy argument(s) corresponding to the aggregate's input argument(s). The extra `anyelement` argument allows the declaration of `array_agg_finalfn` to be valid.

An aggregate function can be made to accept a varying number of arguments by declaring its last argument as a `VARIADIC` array, in much the same fashion as for regular functions; see Section 35.4.5. The aggregate's transition function(s) must have the same array type as their last argument. The transition function(s) typically would also be marked `VARIADIC`, but this is not strictly required.

> **Note:** Variadic aggregates are easily misused in connection with the `ORDER BY` option (see Section 4.2.7), since the parser cannot tell whether the wrong number of actual arguments have been given in such a combination. Keep in mind that everything to the right of `ORDER BY` is a sort key, not an argument to the aggregate. For example, in
>
> ```
> SELECT myaggregate(a ORDER BY a, b, c) FROM ...
> ```
>
> the parser will see this as a single aggregate function argument and three sort keys. However, the user might have intended
>
> ```
> SELECT myaggregate(a, b, c ORDER BY a) FROM ...
> ```
>
> If `myaggregate` is variadic, both these calls could be perfectly valid.
>
> For the same reason, it's wise to think twice before creating aggregate functions with the same names and different numbers of regular arguments.

35.10.3. Ordered-Set Aggregates

The aggregates we have been describing so far are "normal" aggregates. PostgreSQL also supports *ordered-set aggregates*, which differ from normal aggregates in two key ways. First, in addition to ordinary aggregated arguments that are evaluated once per input row, an ordered-set aggregate can have "direct" arguments that are evaluated only once per aggregation operation. Second, the syntax for the ordinary aggregated arguments specifies a sort ordering for them explicitly. An ordered-set aggregate is usually used to implement a computation that depends on a specific row ordering, for instance rank or percentile, so that the sort ordering is a required aspect of any call. For example, the built-in definition of `percentile_disc` is equivalent to:

```
CREATE FUNCTION ordered_set_transition(internal, anyelement)
  RETURNS internal ...;
CREATE FUNCTION percentile_disc_final(internal, float8, anyelement)
  RETURNS anyelement ...;

CREATE AGGREGATE percentile_disc (float8 ORDER BY anyelement)
(
    sfunc = ordered_set_transition,
    stype = internal,
    finalfunc = percentile_disc_final,
    finalfunc_extra
);
```

This aggregate takes a `float8` direct argument (the percentile fraction) and an aggregated input that can be of any sortable data type. It could be used to obtain a median household income like this:

```
SELECT percentile_disc(0.5) WITHIN GROUP (ORDER BY income) FROM households;
 percentile_disc
-----------------
           50489
```

Here, `0.5` is a direct argument; it would make no sense for the percentile fraction to be a value varying across rows.

Unlike the case for normal aggregates, the sorting of input rows for an ordered-set aggregate is *not* done behind the scenes, but is the responsibility of the aggregate's support functions. The typical implementation approach is to keep a reference to a "tuplesort" object in the aggregate's state value, feed the incoming rows into that object, and then complete the sorting and read out the data in the final function. This design allows the final function to perform special operations such as injecting additional "hypothetical" rows into the data to be sorted. While normal aggregates can often be implemented with support functions written in PL/pgSQL or another PL language, ordered-set aggregates generally have to be written in C, since their state values aren't definable as any SQL data type. (In the above example, notice that the state value is declared as type `internal` — this is typical.)

The state transition function for an ordered-set aggregate receives the current state value plus the aggregated input values for each row, and returns the updated state value. This is the same definition as for normal aggregates, but note that the direct arguments (if any) are not provided. The final function receives the last state value, the values of the direct arguments if any, and (if `finalfunc_extra` is specified) null values corresponding to the aggregated input(s). As with normal aggregates, `finalfunc_extra` is only really useful if the aggregate is polymorphic; then the extra dummy argument(s) are needed to connect the final function's result type to the aggregate's input type(s).

Currently, ordered-set aggregates cannot be used as window functions, and therefore there is no need for them to support moving-aggregate mode.

35.10.4. Support Functions for Aggregates

A function written in C can detect that it is being called as an aggregate transition or final function by calling `AggCheckCallContext`, for example:

```
if (AggCheckCallContext(fcinfo, NULL))
```

One reason for checking this is that when it is true for a transition function, the first input must be a temporary state value and can therefore safely be modified in-place rather than allocating a new copy. See `int8inc()` for an example. (This is the *only* case where it is safe for a function to modify a pass-by-reference input. In particular, final functions for normal aggregates must not modify their inputs in any case, because in some cases they will be re-executed on the same final state value.)

Another support routine available to aggregate functions written in C is `AggGetAggref`, which returns the `Aggref` parse node that defines the aggregate call. This is mainly useful for ordered-set aggregates, which can inspect the substructure of the `Aggref` node to find out what sort ordering they are supposed to implement. Examples can be found in `orderedsetaggs.c` in the PostgreSQL source code.

35.11. User-defined Types

As described in Section 35.2, PostgreSQL can be extended to support new data types. This section describes how to define new base types, which are data types defined below the level of the SQL language. Creating a new base type requires implementing functions to operate on the type in a low-level language, usually C.

The examples in this section can be found in `complex.sql` and `complex.c` in the `src/tutorial` directory of the source distribution. See the `README` file in that directory for instructions about running the examples.

A user-defined type must always have input and output functions. These functions determine how the type appears in strings (for input by the user and output to the user) and how the type is organized in memory. The input function takes a null-terminated character string as its argument and returns the internal (in memory) representation of the type. The output function takes the internal representation of the type as argument and returns a null-terminated character string. If we want to do anything more with the type than merely store it, we must provide additional functions to implement whatever operations we'd like to have for the type.

Suppose we want to define a type `complex` that represents complex numbers. A natural way to represent a complex number in memory would be the following C structure:

```
typedef struct Complex {
    double      x;
    double      y;
} Complex;
```

We will need to make this a pass-by-reference type, since it's too large to fit into a single `Datum` value.

As the external string representation of the type, we choose a string of the form `(x,y)`.

The input and output functions are usually not hard to write, especially the output function. But when defining the external string representation of the type, remember that you must eventually write a complete and robust parser for that representation as your input function. For instance:

```
PG_FUNCTION_INFO_V1(complex_in);
```

```
Datum
complex_in(PG_FUNCTION_ARGS)
{
    char       *str = PG_GETARG_CSTRING(0);
    double      x,
                y;
    Complex    *result;

    if (sscanf(str, " ( %lf , %lf )", &x, &y) != 2)
        ereport(ERROR,
                (errcode(ERRCODE_INVALID_TEXT_REPRESENTATION),
                 errmsg("invalid input syntax for complex: \"%s\"",
                        str)));

    result = (Complex *) palloc(sizeof(Complex));
    result->x = x;
    result->y = y;
    PG_RETURN_POINTER(result);
}
```

The output function can simply be:

```
PG_FUNCTION_INFO_V1(complex_out);

Datum
complex_out(PG_FUNCTION_ARGS)
{
    Complex    *complex = (Complex *) PG_GETARG_POINTER(0);
    char       *result;

    result = psprintf("(%g,%g)", complex->x, complex->y);
    PG_RETURN_CSTRING(result);
}
```

You should be careful to make the input and output functions inverses of each other. If you do not, you will have severe problems when you need to dump your data into a file and then read it back in. This is a particularly common problem when floating-point numbers are involved.

Optionally, a user-defined type can provide binary input and output routines. Binary I/O is normally faster but less portable than textual I/O. As with textual I/O, it is up to you to define exactly what the external binary representation is. Most of the built-in data types try to provide a machine-independent binary representation. For `complex`, we will piggy-back on the binary I/O converters for type `float8`:

```
PG_FUNCTION_INFO_V1(complex_recv);

Datum
complex_recv(PG_FUNCTION_ARGS)
{
    StringInfo  buf = (StringInfo) PG_GETARG_POINTER(0);
    Complex    *result;

    result = (Complex *) palloc(sizeof(Complex));
    result->x = pq_getmsgfloat8(buf);
    result->y = pq_getmsgfloat8(buf);
```

```
    PG_RETURN_POINTER(result);
}

PG_FUNCTION_INFO_V1(complex_send);

Datum
complex_send(PG_FUNCTION_ARGS)
{
    Complex    *complex = (Complex *) PG_GETARG_POINTER(0);
    StringInfoData buf;

    pq_begintypsend(&buf);
    pq_sendfloat8(&buf, complex->x);
    pq_sendfloat8(&buf, complex->y);
    PG_RETURN_BYTEA_P(pq_endtypsend(&buf));
}
```

Once we have written the I/O functions and compiled them into a shared library, we can define the `complex` type in SQL. First we declare it as a shell type:

```
CREATE TYPE complex;
```

This serves as a placeholder that allows us to reference the type while defining its I/O functions. Now we can define the I/O functions:

```
CREATE FUNCTION complex_in(cstring)
    RETURNS complex
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_out(complex)
    RETURNS cstring
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_recv(internal)
   RETURNS complex
   AS 'filename'
   LANGUAGE C IMMUTABLE STRICT;

CREATE FUNCTION complex_send(complex)
   RETURNS bytea
   AS 'filename'
   LANGUAGE C IMMUTABLE STRICT;
```

Finally, we can provide the full definition of the data type:

```
CREATE TYPE complex (
   internallength = 16,
   input = complex_in,
   output = complex_out,
   receive = complex_recv,
   send = complex_send,
   alignment = double
```

```
);
```

When you define a new base type, PostgreSQL automatically provides support for arrays of that type. The array type typically has the same name as the base type with the underscore character (_) prepended.

Once the data type exists, we can declare additional functions to provide useful operations on the data type. Operators can then be defined atop the functions, and if needed, operator classes can be created to support indexing of the data type. These additional layers are discussed in following sections.

If the values of your data type vary in size (in internal form), you should make the data type TOAST-able (see Section 59.2). You should do this even if the data are always too small to be compressed or stored externally, because TOAST can save space on small data too, by reducing header overhead.

To do this, the internal representation must follow the standard layout for variable-length data: the first four bytes must be a `char[4]` field which is never accessed directly (customarily named `vl_len_`). You must use `SET_VARSIZE()` to store the size of the datum in this field and `VARSIZE()` to retrieve it. The C functions operating on the data type must always be careful to unpack any toasted values they are handed, by using `PG_DETOAST_DATUM`. (This detail is customarily hidden by defining type-specific `GETARG_DATATYPE_P` macros.) Then, when running the `CREATE TYPE` command, specify the internal length as `variable` and select the appropriate storage option.

If the alignment is unimportant (either just for a specific function or because the data type specifies byte alignment anyway) then it's possible to avoid some of the overhead of `PG_DETOAST_DATUM`. You can use `PG_DETOAST_DATUM_PACKED` instead (customarily hidden by defining a `GETARG_DATATYPE_PP` macro) and using the macros `VARSIZE_ANY_EXHDR` and `VARDATA_ANY` to access a potentially-packed datum. Again, the data returned by these macros is not aligned even if the data type definition specifies an alignment. If the alignment is important you must go through the regular `PG_DETOAST_DATUM` interface.

> **Note:** Older code frequently declares `vl_len_` as an `int32` field instead of `char[4]`. This is OK as long as the struct definition has other fields that have at least `int32` alignment. But it is dangerous to use such a struct definition when working with a potentially unaligned datum; the compiler may take it as license to assume the datum actually is aligned, leading to core dumps on architectures that are strict about alignment.

For further details see the description of the CREATE TYPE command.

35.12. User-defined Operators

Every operator is "syntactic sugar" for a call to an underlying function that does the real work; so you must first create the underlying function before you can create the operator. However, an operator is *not merely* syntactic sugar, because it carries additional information that helps the query planner optimize queries that use the operator. The next section will be devoted to explaining that additional information.

PostgreSQL supports left unary, right unary, and binary operators. Operators can be overloaded; that is, the same operator name can be used for different operators that have different numbers and types of operands. When a query is executed, the system determines the operator to call from the number and types of the provided operands.

Here is an example of creating an operator for adding two complex numbers. We assume we've already created the definition of type `complex` (see Section 35.11). First we need a function that does the work, then we can define the operator:

```
CREATE FUNCTION complex_add(complex, complex)
    RETURNS complex
    AS 'filename', 'complex_add'
    LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR + (
    leftarg = complex,
    rightarg = complex,
    procedure = complex_add,
    commutator = +
);
```

Now we could execute a query like this:

```
SELECT (a + b) AS c FROM test_complex;

        c
-----------------
 (5.2,6.05)
 (133.42,144.95)
```

We've shown how to create a binary operator here. To create unary operators, just omit one of `leftarg` (for left unary) or `rightarg` (for right unary). The `procedure` clause and the argument clauses are the only required items in `CREATE OPERATOR`. The `commutator` clause shown in the example is an optional hint to the query optimizer. Further details about `commutator` and other optimizer hints appear in the next section.

35.13. Operator Optimization Information

A PostgreSQL operator definition can include several optional clauses that tell the system useful things about how the operator behaves. These clauses should be provided whenever appropriate, because they can make for considerable speedups in execution of queries that use the operator. But if you provide them, you must be sure that they are right! Incorrect use of an optimization clause can result in slow queries, subtly wrong output, or other Bad Things. You can always leave out an optimization clause if you are not sure about it; the only consequence is that queries might run slower than they need to.

Additional optimization clauses might be added in future versions of PostgreSQL. The ones described here are all the ones that release 9.4.1 understands.

35.13.1. `COMMUTATOR`

The `COMMUTATOR` clause, if provided, names an operator that is the commutator of the operator being defined. We say that operator A is the commutator of operator B if (x A y) equals (y B x) for all possible input values x, y. Notice that B is also the commutator of A. For example, operators $<$ and $>$

for a particular data type are usually each others' commutators, and operator + is usually commutative with itself. But operator – is usually not commutative with anything.

The left operand type of a commutable operator is the same as the right operand type of its commutator, and vice versa. So the name of the commutator operator is all that PostgreSQL needs to be given to look up the commutator, and that's all that needs to be provided in the COMMUTATOR clause.

It's critical to provide commutator information for operators that will be used in indexes and join clauses, because this allows the query optimizer to "flip around" such a clause to the forms needed for different plan types. For example, consider a query with a WHERE clause like tab1.x = tab2.y, where tab1.x and tab2.y are of a user-defined type, and suppose that tab2.y is indexed. The optimizer cannot generate an index scan unless it can determine how to flip the clause around to tab2.y = tab1.x, because the index-scan machinery expects to see the indexed column on the left of the operator it is given. PostgreSQL will *not* simply assume that this is a valid transformation — the creator of the = operator must specify that it is valid, by marking the operator with commutator information.

When you are defining a self-commutative operator, you just do it. When you are defining a pair of commutative operators, things are a little trickier: how can the first one to be defined refer to the other one, which you haven't defined yet? There are two solutions to this problem:

- One way is to omit the COMMUTATOR clause in the first operator that you define, and then provide one in the second operator's definition. Since PostgreSQL knows that commutative operators come in pairs, when it sees the second definition it will automatically go back and fill in the missing COMMUTATOR clause in the first definition.
- The other, more straightforward way is just to include COMMUTATOR clauses in both definitions. When PostgreSQL processes the first definition and realizes that COMMUTATOR refers to a nonexistent operator, the system will make a dummy entry for that operator in the system catalog. This dummy entry will have valid data only for the operator name, left and right operand types, and result type, since that's all that PostgreSQL can deduce at this point. The first operator's catalog entry will link to this dummy entry. Later, when you define the second operator, the system updates the dummy entry with the additional information from the second definition. If you try to use the dummy operator before it's been filled in, you'll just get an error message.

35.13.2. NEGATOR

The NEGATOR clause, if provided, names an operator that is the negator of the operator being defined. We say that operator A is the negator of operator B if both return Boolean results and (x A y) equals NOT (x B y) for all possible inputs x, y. Notice that B is also the negator of A. For example, < and >= are a negator pair for most data types. An operator can never validly be its own negator.

Unlike commutators, a pair of unary operators could validly be marked as each other's negators; that would mean (A x) equals NOT (B x) for all x, or the equivalent for right unary operators.

An operator's negator must have the same left and/or right operand types as the operator to be defined, so just as with COMMUTATOR, only the operator name need be given in the NEGATOR clause.

Providing a negator is very helpful to the query optimizer since it allows expressions like NOT (x = y) to be simplified into x <> y. This comes up more often than you might think, because NOT operations can be inserted as a consequence of other rearrangements.

Pairs of negator operators can be defined using the same methods explained above for commutator pairs.

35.13.3. RESTRICT

The RESTRICT clause, if provided, names a restriction selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) RESTRICT clauses only make sense for binary operators that return boolean. The idea behind a restriction selectivity estimator is to guess what fraction of the rows in a table will satisfy a WHERE-clause condition of the form:

```
column OP constant
```

for the current operator and a particular constant value. This assists the optimizer by giving it some idea of how many rows will be eliminated by WHERE clauses that have this form. (What happens if the constant is on the left, you might be wondering? Well, that's one of the things that COMMUTATOR is for...)

Writing new restriction selectivity estimation functions is far beyond the scope of this chapter, but fortunately you can usually just use one of the system's standard estimators for many of your own operators. These are the standard restriction estimators:

eqsel for =
neqsel for <>
scalarltsel for < or <=
scalargtsel for > or >=

It might seem a little odd that these are the categories, but they make sense if you think about it. = will typically accept only a small fraction of the rows in a table; <> will typically reject only a small fraction. < will accept a fraction that depends on where the given constant falls in the range of values for that table column (which, it just so happens, is information collected by ANALYZE and made available to the selectivity estimator). <= will accept a slightly larger fraction than < for the same comparison constant, but they're close enough to not be worth distinguishing, especially since we're not likely to do better than a rough guess anyhow. Similar remarks apply to > and >=.

You can frequently get away with using either eqsel or neqsel for operators that have very high or very low selectivity, even if they aren't really equality or inequality. For example, the approximate-equality geometric operators use eqsel on the assumption that they'll usually only match a small fraction of the entries in a table.

You can use scalarltsel and scalargtsel for comparisons on data types that have some sensible means of being converted into numeric scalars for range comparisons. If possible, add the data type to those understood by the function convert_to_scalar() in src/backend/utils/adt/selfuncs.c. (Eventually, this function should be replaced by per-data-type functions identified through a column of the pg_type system catalog; but that hasn't happened yet.) If you do not do this, things will still work, but the optimizer's estimates won't be as good as they could be.

There are additional selectivity estimation functions designed for geometric operators in src/backend/utils/adt/geo_selfuncs.c: areasel, positionsel, and contsel. At this writing these are just stubs, but you might want to use them (or even better, improve them) anyway.

35.13.4. JOIN

The JOIN clause, if provided, names a join selectivity estimation function for the operator. (Note that this is a function name, not an operator name.) JOIN clauses only make sense for binary operators

that return boolean. The idea behind a join selectivity estimator is to guess what fraction of the rows in a pair of tables will satisfy a WHERE-clause condition of the form:

```
table1.column1 OP table2.column2
```

for the current operator. As with the RESTRICT clause, this helps the optimizer very substantially by letting it figure out which of several possible join sequences is likely to take the least work.

As before, this chapter will make no attempt to explain how to write a join selectivity estimator function, but will just suggest that you use one of the standard estimators if one is applicable:

eqjoinsel for =
neqjoinsel for <>
scalarltjoinsel for < or <=
scalargtjoinsel for > or >=
areajoinsel for 2D area-based comparisons
positionjoinsel for 2D position-based comparisons
contjoinsel for 2D containment-based comparisons

35.13.5. HASHES

The HASHES clause, if present, tells the system that it is permissible to use the hash join method for a join based on this operator. HASHES only makes sense for a binary operator that returns boolean, and in practice the operator must represent equality for some data type or pair of data types.

The assumption underlying hash join is that the join operator can only return true for pairs of left and right values that hash to the same hash code. If two values get put in different hash buckets, the join will never compare them at all, implicitly assuming that the result of the join operator must be false. So it never makes sense to specify HASHES for operators that do not represent some form of equality. In most cases it is only practical to support hashing for operators that take the same data type on both sides. However, sometimes it is possible to design compatible hash functions for two or more data types; that is, functions that will generate the same hash codes for "equal" values, even though the values have different representations. For example, it's fairly simple to arrange this property when hashing integers of different widths.

To be marked HASHES, the join operator must appear in a hash index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn't exist yet. But attempts to use the operator in hash joins will fail at run time if no such operator family exists. The system needs the operator family to find the data-type-specific hash function(s) for the operator's input data type(s). Of course, you must also create suitable hash functions before you can create the operator family.

Care should be exercised when preparing a hash function, because there are machine-dependent ways in which it might fail to do the right thing. For example, if your data type is a structure in which there might be uninteresting pad bits, you cannot simply pass the whole structure to hash_any. (Unless you write your other operators and functions to ensure that the unused bits are always zero, which is the recommended strategy.) Another example is that on machines that meet the IEEE floating-point standard, negative zero and positive zero are different values (different bit patterns) but they are defined to compare equal. If a float value might contain negative zero then extra steps are needed to ensure it generates the same hash value as positive zero.

A hash-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not

the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a hash operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

> **Note:** The function underlying a hash-joinable operator must be marked immutable or stable. If it is volatile, the system will never attempt to use the operator for a hash join.

> **Note:** If a hash-joinable operator has an underlying function that is marked strict, the function must also be complete: that is, it should return true or false, never null, for any two nonnull inputs. If this rule is not followed, hash-optimization of `IN` operations might generate wrong results. (Specifically, `IN` might return false where the correct answer according to the standard would be null; or it might yield an error complaining that it wasn't prepared for a null result.)

35.13.6. `MERGES`

The `MERGES` clause, if present, tells the system that it is permissible to use the merge-join method for a join based on this operator. `MERGES` only makes sense for a binary operator that returns `boolean`, and in practice the operator must represent equality for some data type or pair of data types.

Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. So, both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at the "same place" in the sort order. In practice this means that the join operator must behave like equality. But it is possible to merge-join two distinct data types so long as they are logically compatible. For example, the `smallint`-versus-`integer` equality operator is merge-joinable. We only need sorting operators that will bring both data types into a logically compatible sequence.

To be marked `MERGES`, the join operator must appear as an equality member of a `btree` index operator family. This is not enforced when you create the operator, since of course the referencing operator family couldn't exist yet. But the operator will not actually be used for merge joins unless a matching operator family can be found. The `MERGES` flag thus acts as a hint to the planner that it's worth looking for a matching operator family.

A merge-joinable operator must have a commutator (itself if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. If this is not the case, planner errors might occur when the operator is used. Also, it is a good idea (but not strictly required) for a `btree` operator family that supports multiple data types to provide equality operators for every combination of the data types; this allows better optimization.

> **Note:** The function underlying a merge-joinable operator must be marked immutable or stable. If it is volatile, the system will never attempt to use the operator for a merge join.

35.14. Interfacing Extensions To Indexes

The procedures described thus far let you define new types, new functions, and new operators. However, we cannot yet define an index on a column of a new data type. To do this, we must define an *operator class* for the new data type. Later in this section, we will illustrate this concept in an example: a new operator class for the B-tree index method that stores and sorts complex numbers in ascending absolute value order.

Operator classes can be grouped into *operator families* to show the relationships between semantically compatible classes. When only a single data type is involved, an operator class is sufficient, so we'll focus on that case first and then return to operator families.

35.14.1. Index Methods and Operator Classes

The `pg_am` table contains one row for every index method (internally known as access method). Support for regular access to tables is built into PostgreSQL, but all index methods are described in `pg_am`. It is possible to add a new index method by defining the required interface routines and then creating a row in `pg_am` — but that is beyond the scope of this chapter (see Chapter 55).

The routines for an index method do not directly know anything about the data types that the index method will operate on. Instead, an *operator class* identifies the set of operations that the index method needs to use to work with a particular data type. Operator classes are so called because one thing they specify is the set of `WHERE`-clause operators that can be used with an index (i.e., can be converted into an index-scan qualification). An operator class can also specify some *support procedures* that are needed by the internal operations of the index method, but do not directly correspond to any `WHERE`-clause operator that can be used with the index.

It is possible to define multiple operator classes for the same data type and index method. By doing this, multiple sets of indexing semantics can be defined for a single data type. For example, a B-tree index requires a sort ordering to be defined for each data type it works on. It might be useful for a complex-number data type to have one B-tree operator class that sorts the data by complex absolute value, another that sorts by real part, and so on. Typically, one of the operator classes will be deemed most commonly useful and will be marked as the default operator class for that data type and index method.

The same operator class name can be used for several different index methods (for example, both B-tree and hash index methods have operator classes named `int4_ops`), but each such class is an independent entity and must be defined separately.

35.14.2. Index Method Strategies

The operators associated with an operator class are identified by "strategy numbers", which serve to identify the semantics of each operator within the context of its operator class. For example, B-trees impose a strict ordering on keys, lesser to greater, and so operators like "less than" and "greater than or equal to" are interesting with respect to a B-tree. Because PostgreSQL allows the user to define operators, PostgreSQL cannot look at the name of an operator (e.g., < or >=) and tell what kind of comparison it is. Instead, the index method defines a set of "strategies", which can be thought of as generalized operators. Each operator class specifies which actual operator corresponds to each strategy for a particular data type and interpretation of the index semantics.

The B-tree index method defines five strategies, shown in Table 35-2.

Table 35-2. B-tree Strategies

Operation	Strategy Number
less than	1
less than or equal	2
equal	3
greater than or equal	4
greater than	5

Hash indexes support only equality comparisons, and so they use only one strategy, shown in Table 35-3.

Table 35-3. Hash Strategies

Operation	Strategy Number
equal	1

GiST indexes are more flexible: they do not have a fixed set of strategies at all. Instead, the "consistency" support routine of each particular GiST operator class interprets the strategy numbers however it likes. As an example, several of the built-in GiST index operator classes index two-dimensional geometric objects, providing the "R-tree" strategies shown in Table 35-4. Four of these are true two-dimensional tests (overlaps, same, contains, contained by); four of them consider only the X direction; and the other four provide the same tests in the Y direction.

Table 35-4. GiST Two-Dimensional "R-tree" Strategies

Operation	Strategy Number
strictly left of	1
does not extend to right of	2
overlaps	3
does not extend to left of	4
strictly right of	5
same	6
contains	7
contained by	8
does not extend above	9
strictly below	10
strictly above	11
does not extend below	12

SP-GiST indexes are similar to GiST indexes in flexibility: they don't have a fixed set of strategies. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in operator classes for points are shown in Table 35-5.

Table 35-5. SP-GiST Point Strategies

Operation	Strategy Number

Operation	Strategy Number
strictly left of	1
strictly right of	5
same	6
contained by	8
strictly below	10
strictly above	11

GIN indexes are similar to GiST and SP-GiST indexes, in that they don't have a fixed set of strategies either. Instead the support routines of each operator class interpret the strategy numbers according to the operator class's definition. As an example, the strategy numbers used by the built-in operator classes for arrays are shown in Table 35-6.

Table 35-6. GIN Array Strategies

Operation	Strategy Number
overlap	1
contains	2
is contained by	3
equal	4

Notice that all the operators listed above return Boolean values. In practice, all operators defined as index method search operators must return type `boolean`, since they must appear at the top level of a `WHERE` clause to be used with an index. (Some index access methods also support *ordering operators*, which typically don't return Boolean values; that feature is discussed in Section 35.14.7.)

35.14.3. Index Method Support Routines

Strategies aren't usually enough information for the system to figure out how to use an index. In practice, the index methods require additional support routines in order to work. For example, the B-tree index method must be able to compare two keys and determine whether one is greater than, equal to, or less than the other. Similarly, the hash index method must be able to compute hash codes for key values. These operations do not correspond to operators used in qualifications in SQL commands; they are administrative routines used by the index methods, internally.

Just as with strategies, the operator class identifies which specific functions should play each of these roles for a given data type and semantic interpretation. The index method defines the set of functions it needs, and the operator class identifies the correct functions to use by assigning them to the "support function numbers" specified by the index method.

B-trees require a single support function, and allow a second one to be supplied at the operator class author's option, as shown in Table 35-7.

Table 35-7. B-tree Support Functions

Function	Support Number

Function	Support Number
Compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
Return the addresses of C-callable sort support function(s), as documented in `utils/sortsupport.h` (optional)	2

Hash indexes require one support function, shown in Table 35-8.

Table 35-8. Hash Support Functions

Function	Support Number
Compute the hash value for a key	1

GiST indexes require seven support functions, with an optional eighth, as shown in Table 35-9. (For more information see Chapter 56.)

Table 35-9. GiST Support Functions

Function	Description	Support Number
`consistent`	determine whether key satisfies the query qualifier	1
`union`	compute union of a set of keys	2
`compress`	compute a compressed representation of a key or value to be indexed	3
`decompress`	compute a decompressed representation of a compressed key	4
`penalty`	compute penalty for inserting new key into subtree with given subtree's key	5
`picksplit`	determine which entries of a page are to be moved to the new page and compute the union keys for resulting pages	6
`equal`	compare two keys and return true if they are equal	7
`distance`	determine distance from key to query value (optional)	8

SP-GiST indexes require five support functions, as shown in Table 35-10. (For more information see Chapter 57.)

Table 35-10. SP-GiST Support Functions

Function	Description	Support Number

Function	Description	Support Number
config	provide basic information about the operator class	1
choose	determine how to insert a new value into an inner tuple	2
picksplit	determine how to partition a set of values	3
inner_consistent	determine which sub-partitions need to be searched for a query	4
leaf_consistent	determine whether key satisfies the query qualifier	5

GIN indexes require four support functions, with an optional fifth, as shown in Table 35-11. (For more information see Chapter 58.)

Table 35-11. GIN Support Functions

Function	Description	Support Number
compare	compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second	1
extractValue	extract keys from a value to be indexed	2
extractQuery	extract keys from a query condition	3
consistent	determine whether value matches query condition (Boolean variant) (optional if support function 6 is present)	4
comparePartial	compare partial key from query and key from index, and return an integer less than zero, zero, or greater than zero, indicating whether GIN should ignore this index entry, treat the entry as a match, or stop the index scan (optional)	5
triConsistent	determine whether value matches query condition (ternary variant) (optional if support function 4 is present)	6

Unlike search operators, support functions return whichever data type the particular index method expects; for example in the case of the comparison function for B-trees, a signed integer. The number and types of the arguments to each support function are likewise dependent on the index method. For B-tree and hash the comparison and hashing support functions take the same input data types as do the operators included in the operator class, but this is not the case for most GiST, SP-GiST, and GIN

support functions.

35.14.4. An Example

Now that we have seen the ideas, here is the promised example of creating a new operator class. (You can find a working copy of this example in `src/tutorial/complex.c` and `src/tutorial/complex.sql` in the source distribution.) The operator class encapsulates operators that sort complex numbers in absolute value order, so we choose the name `complex_abs_ops`. First, we need a set of operators. The procedure for defining operators was discussed in Section 35.12. For an operator class on B-trees, the operators we require are:

- absolute-value less-than (strategy 1)
- absolute-value less-than-or-equal (strategy 2)
- absolute-value equal (strategy 3)
- absolute-value greater-than-or-equal (strategy 4)
- absolute-value greater-than (strategy 5)

The least error-prone way to define a related set of comparison operators is to write the B-tree comparison support function first, and then write the other functions as one-line wrappers around the support function. This reduces the odds of getting inconsistent results for corner cases. Following this approach, we first write:

```
#define Mag(c)  ((c)->x*(c)->x + (c)->y*(c)->y)

static int
complex_abs_cmp_internal(Complex *a, Complex *b)
{
    double      amag = Mag(a),
                bmag = Mag(b);

    if (amag < bmag)
        return -1;
    if (amag > bmag)
        return 1;
    return 0;
}
```

Now the less-than function looks like:

```
PG_FUNCTION_INFO_V1(complex_abs_lt);

Datum
complex_abs_lt(PG_FUNCTION_ARGS)
{
    Complex    *a = (Complex *) PG_GETARG_POINTER(0);
    Complex    *b = (Complex *) PG_GETARG_POINTER(1);

    PG_RETURN_BOOL(complex_abs_cmp_internal(a, b) < 0);
}
```

The other four functions differ only in how they compare the internal function's result to zero.

Next we declare the functions and the operators based on the functions to SQL:

```
CREATE FUNCTION complex_abs_lt(complex, complex) RETURNS bool
    AS 'filename', 'complex_abs_lt'
    LANGUAGE C IMMUTABLE STRICT;

CREATE OPERATOR < (
   leftarg = complex, rightarg = complex, procedure = complex_abs_lt,
   commutator = > , negator = >= ,
   restrict = scalarltsel, join = scalarltjoinsel
);
```

It is important to specify the correct commutator and negator operators, as well as suitable restriction and join selectivity functions, otherwise the optimizer will be unable to make effective use of the index. Note that the less-than, equal, and greater-than cases should use different selectivity functions.

Other things worth noting are happening here:

- There can only be one operator named, say, = and taking type `complex` for both operands. In this case we don't have any other operator = for `complex`, but if we were building a practical data type we'd probably want = to be the ordinary equality operation for complex numbers (and not the equality of the absolute values). In that case, we'd need to use some other operator name for `complex_abs_eq`.
- Although PostgreSQL can cope with functions having the same SQL name as long as they have different argument data types, C can only cope with one global function having a given name. So we shouldn't name the C function something simple like `abs_eq`. Usually it's a good practice to include the data type name in the C function name, so as not to conflict with functions for other data types.
- We could have made the SQL name of the function `abs_eq`, relying on PostgreSQL to distinguish it by argument data types from any other SQL function of the same name. To keep the example simple, we make the function have the same names at the C level and SQL level.

The next step is the registration of the support routine required by B-trees. The example C code that implements this is in the same file that contains the operator functions. This is how we declare the function:

```
CREATE FUNCTION complex_abs_cmp(complex, complex)
    RETURNS integer
    AS 'filename'
    LANGUAGE C IMMUTABLE STRICT;
```

Now that we have the required operators and support routine, we can finally create the operator class:

```
CREATE OPERATOR CLASS complex_abs_ops
    DEFAULT FOR TYPE complex USING btree AS
        OPERATOR        1       < ,
        OPERATOR        2       <= ,
        OPERATOR        3       = ,
        OPERATOR        4       >= ,
        OPERATOR        5       > ,
        FUNCTION        1       complex_abs_cmp(complex, complex);
```

And we're done! It should now be possible to create and use B-tree indexes on `complex` columns.

We could have written the operator entries more verbosely, as in:

```
OPERATOR        1       < (complex, complex) ,
```

but there is no need to do so when the operators take the same data type we are defining the operator class for.

The above example assumes that you want to make this new operator class the default B-tree operator class for the `complex` data type. If you don't, just leave out the word `DEFAULT`.

35.14.5. Operator Classes and Operator Families

So far we have implicitly assumed that an operator class deals with only one data type. While there certainly can be only one data type in a particular index column, it is often useful to index operations that compare an indexed column to a value of a different data type. Also, if there is use for a cross-data-type operator in connection with an operator class, it is often the case that the other data type has a related operator class of its own. It is helpful to make the connections between related classes explicit, because this can aid the planner in optimizing SQL queries (particularly for B-tree operator classes, since the planner contains a great deal of knowledge about how to work with them).

To handle these needs, PostgreSQL uses the concept of an *operator family*. An operator family contains one or more operator classes, and can also contain indexable operators and corresponding support functions that belong to the family as a whole but not to any single class within the family. We say that such operators and functions are "loose" within the family, as opposed to being bound into a specific class. Typically each operator class contains single-data-type operators while cross-data-type operators are loose in the family.

All the operators and functions in an operator family must have compatible semantics, where the compatibility requirements are set by the index method. You might therefore wonder why bother to single out particular subsets of the family as operator classes; and indeed for many purposes the class divisions are irrelevant and the family is the only interesting grouping. The reason for defining operator classes is that they specify how much of the family is needed to support any particular index. If there is an index using an operator class, then that operator class cannot be dropped without dropping the index — but other parts of the operator family, namely other operator classes and loose operators, could be dropped. Thus, an operator class should be specified to contain the minimum set of operators and functions that are reasonably needed to work with an index on a specific data type, and then related but non-essential operators can be added as loose members of the operator family.

As an example, PostgreSQL has a built-in B-tree operator family `integer_ops`, which includes operator classes `int8_ops`, `int4_ops`, and `int2_ops` for indexes on `bigint` (`int8`), `integer` (`int4`), and `smallint` (`int2`) columns respectively. The family also contains cross-data-type comparison operators allowing any two of these types to be compared, so that an index on one of these types can be searched using a comparison value of another type. The family could be duplicated by these definitions:

```
CREATE OPERATOR FAMILY integer_ops USING btree;

CREATE OPERATOR CLASS int8_ops
DEFAULT FOR TYPE int8 USING btree FAMILY integer_ops AS
  -- standard int8 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
```

```
  FUNCTION 1 btint8cmp(int8, int8) ,
  FUNCTION 2 btint8sortsupport(internal) ;

CREATE OPERATOR CLASS int4_ops
DEFAULT FOR TYPE int4 USING btree FAMILY integer_ops AS
  -- standard int4 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint4cmp(int4, int4) ,
  FUNCTION 2 btint4sortsupport(internal) ;

CREATE OPERATOR CLASS int2_ops
DEFAULT FOR TYPE int2 USING btree FAMILY integer_ops AS
  -- standard int2 comparisons
  OPERATOR 1 < ,
  OPERATOR 2 <= ,
  OPERATOR 3 = ,
  OPERATOR 4 >= ,
  OPERATOR 5 > ,
  FUNCTION 1 btint2cmp(int2, int2) ,
  FUNCTION 2 btint2sortsupport(internal) ;

ALTER OPERATOR FAMILY integer_ops USING btree ADD
  -- cross-type comparisons int8 vs int2
  OPERATOR 1 < (int8, int2) ,
  OPERATOR 2 <= (int8, int2) ,
  OPERATOR 3 = (int8, int2) ,
  OPERATOR 4 >= (int8, int2) ,
  OPERATOR 5 > (int8, int2) ,
  FUNCTION 1 btint82cmp(int8, int2) ,

  -- cross-type comparisons int8 vs int4
  OPERATOR 1 < (int8, int4) ,
  OPERATOR 2 <= (int8, int4) ,
  OPERATOR 3 = (int8, int4) ,
  OPERATOR 4 >= (int8, int4) ,
  OPERATOR 5 > (int8, int4) ,
  FUNCTION 1 btint84cmp(int8, int4) ,

  -- cross-type comparisons int4 vs int2
  OPERATOR 1 < (int4, int2) ,
  OPERATOR 2 <= (int4, int2) ,
  OPERATOR 3 = (int4, int2) ,
  OPERATOR 4 >= (int4, int2) ,
  OPERATOR 5 > (int4, int2) ,
  FUNCTION 1 btint42cmp(int4, int2) ,

  -- cross-type comparisons int4 vs int8
  OPERATOR 1 < (int4, int8) ,
  OPERATOR 2 <= (int4, int8) ,
  OPERATOR 3 = (int4, int8) ,
  OPERATOR 4 >= (int4, int8) ,
  OPERATOR 5 > (int4, int8) ,
  FUNCTION 1 btint48cmp(int4, int8) ,
```

```
-- cross-type comparisons int2 vs int8
OPERATOR 1 < (int2, int8) ,
OPERATOR 2 <= (int2, int8) ,
OPERATOR 3 = (int2, int8) ,
OPERATOR 4 >= (int2, int8) ,
OPERATOR 5 > (int2, int8) ,
FUNCTION 1 btint28cmp(int2, int8) ,

-- cross-type comparisons int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ;
```

Notice that this definition "overloads" the operator strategy and support function numbers: each number occurs multiple times within the family. This is allowed so long as each instance of a particular number has distinct input data types. The instances that have both input types equal to an operator class's input type are the primary operators and support functions for that operator class, and in most cases should be declared as part of the operator class rather than as loose members of the family.

In a B-tree operator family, all the operators in the family must sort compatibly, meaning that the transitive laws hold across all the data types supported by the family: "if A = B and B = C, then A = C", and "if A < B and B < C, then A < C". Moreover, implicit or binary coercion casts between types represented in the operator family must not change the associated sort ordering. For each operator in the family there must be a support function having the same two input data types as the operator. It is recommended that a family be complete, i.e., for each combination of data types, all operators are included. Each operator class should include just the non-cross-type operators and support function for its data type.

To build a multiple-data-type hash operator family, compatible hash support functions must be created for each data type supported by the family. Here compatibility means that the functions are guaranteed to return the same hash code for any two values that are considered equal by the family's equality operators, even when the values are of different types. This is usually difficult to accomplish when the types have different physical representations, but it can be done in some cases. Furthermore, casting a value from one data type represented in the operator family to another data type also represented in the operator family via an implicit or binary coercion cast must not change the computed hash value. Notice that there is only one support function per data type, not one per equality operator. It is recommended that a family be complete, i.e., provide an equality operator for each combination of data types. Each operator class should include just the non-cross-type equality operator and the support function for its data type.

GiST, SP-GiST, and GIN indexes do not have any explicit notion of cross-data-type operations. The set of operators supported is just whatever the primary support functions for a given operator class can handle.

> **Note:** Prior to PostgreSQL 8.3, there was no concept of operator families, and so any cross-data-type operators intended to be used with an index had to be bound directly into the index's operator class. While this approach still works, it is deprecated because it makes an index's dependencies too broad, and because the planner can handle cross-data-type comparisons more effectively when both data types have operators in the same operator family.

35.14.6. System Dependencies on Operator Classes

PostgreSQL uses operator classes to infer the properties of operators in more ways than just whether they can be used with indexes. Therefore, you might want to create operator classes even if you have no intention of indexing any columns of your data type.

In particular, there are SQL features such as `ORDER BY` and `DISTINCT` that require comparison and sorting of values. To implement these features on a user-defined data type, PostgreSQL looks for the default B-tree operator class for the data type. The "equals" member of this operator class defines the system's notion of equality of values for `GROUP BY` and `DISTINCT`, and the sort ordering imposed by the operator class defines the default `ORDER BY` ordering.

Comparison of arrays of user-defined types also relies on the semantics defined by the default B-tree operator class.

If there is no default B-tree operator class for a data type, the system will look for a default hash operator class. But since that kind of operator class only provides equality, in practice it is only enough to support array equality.

When there is no default operator class for a data type, you will get errors like "could not identify an ordering operator" if you try to use these SQL features with the data type.

> **Note:** In PostgreSQL versions before 7.4, sorting and grouping operations would implicitly use operators named =, <, and >. The new behavior of relying on default operator classes avoids having to make any assumption about the behavior of operators with particular names.

Another important point is that an operator that appears in a hash operator family is a candidate for hash joins, hash aggregation, and related optimizations. The hash operator family is essential here since it identifies the hash function(s) to use.

35.14.7. Ordering Operators

Some index access methods (currently, only GiST) support the concept of *ordering operators*. What we have been discussing so far are *search operators*. A search operator is one for which the index can be searched to find all rows satisfying `WHERE` *`indexed_column operator constant`*. Note that nothing is promised about the order in which the matching rows will be returned. In contrast, an ordering operator does not restrict the set of rows that can be returned, but instead determines their order. An ordering operator is one for which the index can be scanned to return rows in the order represented by `ORDER BY` *`indexed_column operator constant`*. The reason for defining ordering operators that way is that it supports nearest-neighbor searches, if the operator is one that measures distance. For example, a query like

```
SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT 10;
```

finds the ten places closest to a given target point. A GiST index on the location column can do this efficiently because <-> is an ordering operator.

While search operators have to return Boolean results, ordering operators usually return some other type, such as float or numeric for distances. This type is normally not the same as the data type being indexed. To avoid hard-wiring assumptions about the behavior of different data types, the definition of an ordering operator is required to name a B-tree operator family that specifies the sort ordering of the result data type. As was stated in the previous section, B-tree operator families define PostgreSQL's notion of ordering, so this is a natural representation. Since the point <-> operator returns `float8`, it could be specified in an operator class creation command like this:

```
OPERATOR 15    <-> (point, point) FOR ORDER BY float_ops
```

where `float_ops` is the built-in operator family that includes operations on `float8`. This declaration states that the index is able to return rows in order of increasing values of the `<->` operator.

35.14.8. Special Features of Operator Classes

There are two special features of operator classes that we have not discussed yet, mainly because they are not useful with the most commonly used index methods.

Normally, declaring an operator as a member of an operator class (or family) means that the index method can retrieve exactly the set of rows that satisfy a `WHERE` condition using the operator. For example:

```
SELECT * FROM table WHERE integer_column < 4;
```

can be satisfied exactly by a B-tree index on the integer column. But there are cases where an index is useful as an inexact guide to the matching rows. For example, if a GiST index stores only bounding boxes for geometric objects, then it cannot exactly satisfy a `WHERE` condition that tests overlap between nonrectangular objects such as polygons. Yet we could use the index to find objects whose bounding box overlaps the bounding box of the target object, and then do the exact overlap test only on the objects found by the index. If this scenario applies, the index is said to be "lossy" for the operator. Lossy index searches are implemented by having the index method return a *recheck* flag when a row might or might not really satisfy the query condition. The core system will then test the original query condition on the retrieved row to see whether it should be returned as a valid match. This approach works if the index is guaranteed to return all the required rows, plus perhaps some additional rows, which can be eliminated by performing the original operator invocation. The index methods that support lossy searches (currently, GiST, SP-GiST and GIN) allow the support functions of individual operator classes to set the recheck flag, and so this is essentially an operator-class feature.

Consider again the situation where we are storing in the index only the bounding box of a complex object such as a polygon. In this case there's not much value in storing the whole polygon in the index entry — we might as well store just a simpler object of type `box`. This situation is expressed by the `STORAGE` option in `CREATE OPERATOR CLASS`: we'd write something like:

```
CREATE OPERATOR CLASS polygon_ops
    DEFAULT FOR TYPE polygon USING gist AS
        ...
        STORAGE box;
```

At present, only the GiST and GIN index methods support a `STORAGE` type that's different from the column data type. The GiST `compress` and `decompress` support routines must deal with data-type conversion when `STORAGE` is used. In GIN, the `STORAGE` type identifies the type of the "key" values, which normally is different from the type of the indexed column — for example, an operator class for integer-array columns might have keys that are just integers. The GIN `extractValue` and `extractQuery` support routines are responsible for extracting keys from indexed values.

35.15. Packaging Related Objects into an Extension

A useful extension to PostgreSQL typically includes multiple SQL objects; for example, a new data type will require new functions, new operators, and probably new index operator classes. It is helpful

to collect all these objects into a single package to simplify database management. PostgreSQL calls such a package an *extension*. To define an extension, you need at least a *script file* that contains the SQL commands to create the extension's objects, and a *control file* that specifies a few basic properties of the extension itself. If the extension includes C code, there will typically also be a shared library file into which the C code has been built. Once you have these files, a simple CREATE EXTENSION command loads the objects into your database.

The main advantage of using an extension, rather than just running the SQL script to load a bunch of "loose" objects into your database, is that PostgreSQL will then understand that the objects of the extension go together. You can drop all the objects with a single DROP EXTENSION command (no need to maintain a separate "uninstall" script). Even more useful, pg_dump knows that it should not dump the individual member objects of the extension — it will just include a `CREATE EXTENSION` command in dumps, instead. This vastly simplifies migration to a new version of the extension that might contain more or different objects than the old version. Note however that you must have the extension's control, script, and other files available when loading such a dump into a new database.

PostgreSQL will not let you drop an individual object contained in an extension, except by dropping the whole extension. Also, while you can change the definition of an extension member object (for example, via `CREATE OR REPLACE FUNCTION` for a function), bear in mind that the modified definition will not be dumped by pg_dump. Such a change is usually only sensible if you concurrently make the same change in the extension's script file. (But there are special provisions for tables containing configuration data; see below.)

The extension mechanism also has provisions for packaging modification scripts that adjust the definitions of the SQL objects contained in an extension. For example, if version 1.1 of an extension adds one function and changes the body of another function compared to 1.0, the extension author can provide an *update script* that makes just those two changes. The `ALTER EXTENSION UPDATE` command can then be used to apply these changes and track which version of the extension is actually installed in a given database.

The kinds of SQL objects that can be members of an extension are shown in the description of ALTER EXTENSION. Notably, objects that are database-cluster-wide, such as databases, roles, and tablespaces, cannot be extension members since an extension is only known within one database. (Although an extension script is not prohibited from creating such objects, if it does so they will not be tracked as part of the extension.) Also notice that while a table can be a member of an extension, its subsidiary objects such as indexes are not directly considered members of the extension. Another important point is that schemas can belong to extensions, but not vice versa: an extension as such has an unqualified name and does not exist "within" any schema. The extension's member objects, however, will belong to schemas whenever appropriate for their object types. It may or may not be appropriate for an extension to own the schema(s) its member objects are within.

35.15.1. Extension Files

The CREATE EXTENSION command relies on a control file for each extension, which must be named the same as the extension with a suffix of `.control`, and must be placed in the installation's `SHAREDIR/extension` directory. There must also be at least one SQL script file, which follows the naming pattern *`extension--version`*`.sql` (for example, `foo--1.0.sql` for version `1.0` of extension `foo`). By default, the script file(s) are also placed in the `SHAREDIR/extension` directory; but the control file can specify a different directory for the script file(s).

The file format for an extension control file is the same as for the `postgresql.conf` file, namely a list of *`parameter_name`* = *`value`* assignments, one per line. Blank lines and comments introduced by `#` are allowed. Be sure to quote any value that is not a single word or number.

A control file can set the following parameters:

`directory` (`string`)

The directory containing the extension's SQL script file(s). Unless an absolute path is given, the name is relative to the installation's `SHAREDIR` directory. The default behavior is equivalent to specifying `directory = 'extension'`.

`default_version` (`string`)

The default version of the extension (the one that will be installed if no version is specified in `CREATE EXTENSION`). Although this can be omitted, that will result in `CREATE EXTENSION` failing if no `VERSION` option appears, so you generally don't want to do that.

`comment` (`string`)

A comment (any string) about the extension. Alternatively, the comment can be set by means of the COMMENT command in the script file.

`encoding` (`string`)

The character set encoding used by the script file(s). This should be specified if the script files contain any non-ASCII characters. Otherwise the files will be assumed to be in the database encoding.

`module_pathname` (`string`)

The value of this parameter will be substituted for each occurrence of `MODULE_PATHNAME` in the script file(s). If it is not set, no substitution is made. Typically, this is set to `$libdir/`*`shared_library_name`* and then `MODULE_PATHNAME` is used in `CREATE FUNCTION` commands for C-language functions, so that the script files do not need to hard-wire the name of the shared library.

`requires` (`string`)

A list of names of extensions that this extension depends on, for example `requires = 'foo, bar'`. Those extensions must be installed before this one can be installed.

`superuser` (`boolean`)

If this parameter is `true` (which is the default), only superusers can create the extension or update it to a new version. If it is set to `false`, just the privileges required to execute the commands in the installation or update script are required.

`relocatable` (`boolean`)

An extension is *relocatable* if it is possible to move its contained objects into a different schema after initial creation of the extension. The default is `false`, i.e. the extension is not relocatable. See below for more information.

`schema` (`string`)

This parameter can only be set for non-relocatable extensions. It forces the extension to be loaded into exactly the named schema and not any other. See below for more information.

In addition to the primary control file *`extension`*`.control`, an extension can have secondary control files named in the style *`extension--version`*`.control`. If supplied, these must be located in the script file directory. Secondary control files follow the same format as the primary control file. Any parameters set in a secondary control file override the primary control file when installing or updating to that version of the extension. However, the parameters `directory` and `default_version` cannot be set in a secondary control file.

An extension's SQL script files can contain any SQL commands, except for transaction control commands (`BEGIN`, `COMMIT`, etc) and commands that cannot be executed inside a transaction block (such as `VACUUM`). This is because the script files are implicitly executed within a transaction block.

An extension's SQL script files can also contain lines beginning with `\echo`, which will be ignored (treated as comments) by the extension mechanism. This provision is commonly used to throw an error if the script file is fed to psql rather than being loaded via `CREATE EXTENSION` (see example script below). Without that, users might accidentally load the extension's contents as "loose" objects rather than as an extension, a state of affairs that's a bit tedious to recover from.

While the script files can contain any characters allowed by the specified encoding, control files should contain only plain ASCII, because there is no way for PostgreSQL to know what encoding a control file is in. In practice this is only an issue if you want to use non-ASCII characters in the extension's comment. Recommended practice in that case is to not use the control file `comment` parameter, but instead use `COMMENT ON EXTENSION` within a script file to set the comment.

35.15.2. Extension Relocatability

Users often wish to load the objects contained in an extension into a different schema than the extension's author had in mind. There are three supported levels of relocatability:

- A fully relocatable extension can be moved into another schema at any time, even after it's been loaded into a database. This is done with the `ALTER EXTENSION SET SCHEMA` command, which automatically renames all the member objects into the new schema. Normally, this is only possible if the extension contains no internal assumptions about what schema any of its objects are in. Also, the extension's objects must all be in one schema to begin with (ignoring objects that do not belong to any schema, such as procedural languages). Mark a fully relocatable extension by setting `relocatable = true` in its control file.
- An extension might be relocatable during installation but not afterwards. This is typically the case if the extension's script file needs to reference the target schema explicitly, for example in setting `search_path` properties for SQL functions. For such an extension, set `relocatable = false` in its control file, and use `@extschema@` to refer to the target schema in the script file. All occurrences of this string will be replaced by the actual target schema's name before the script is executed. The user can set the target schema using the `SCHEMA` option of `CREATE EXTENSION`.
- If the extension does not support relocation at all, set `relocatable = false` in its control file, and also set `schema` to the name of the intended target schema. This will prevent use of the `SCHEMA` option of `CREATE EXTENSION`, unless it specifies the same schema named in the control file. This choice is typically necessary if the extension contains internal assumptions about schema names that can't be replaced by uses of `@extschema@`. The `@extschema@` substitution mechanism is available in this case too, although it is of limited use since the schema name is determined by the control file.

In all cases, the script file will be executed with search_path initially set to point to the target schema; that is, `CREATE EXTENSION` does the equivalent of this:

```
SET LOCAL search_path TO @extschema@;
```

This allows the objects created by the script file to go into the target schema. The script file can change `search_path` if it wishes, but that is generally undesirable. `search_path` is restored to its previous setting upon completion of `CREATE EXTENSION`.

The target schema is determined by the `schema` parameter in the control file if that is given, otherwise by the `SCHEMA` option of `CREATE EXTENSION` if that is given, otherwise the current default object creation schema (the first one in the caller's `search_path`). When the control file `schema` parameter is used, the target schema will be created if it doesn't already exist, but in the other two cases it must already exist.

If any prerequisite extensions are listed in `requires` in the control file, their target schemas are appended to the initial setting of `search_path`. This allows their objects to be visible to the new extension's script file.

Although a non-relocatable extension can contain objects spread across multiple schemas, it is usually desirable to place all the objects meant for external use into a single schema, which is considered the extension's target schema. Such an arrangement works conveniently with the default setting of `search_path` during creation of dependent extensions.

35.15.3. Extension Configuration Tables

Some extensions include configuration tables, which contain data that might be added or changed by the user after installation of the extension. Ordinarily, if a table is part of an extension, neither the table's definition nor its content will be dumped by pg_dump. But that behavior is undesirable for a configuration table; any data changes made by the user need to be included in dumps, or the extension will behave differently after a dump and reload.

To solve this problem, an extension's script file can mark a table it has created as a configuration table, which will cause pg_dump to include the table's contents (not its definition) in dumps. To do that, call the function `pg_extension_config_dump(regclass, text)` after creating the table, for example

```
CREATE TABLE my_config (key text, value text);

SELECT pg_catalog.pg_extension_config_dump('my_config', '');
```

Any number of tables can be marked this way.

When the second argument of `pg_extension_config_dump` is an empty string, the entire contents of the table are dumped by pg_dump. This is usually only correct if the table is initially empty as created by the extension script. If there is a mixture of initial data and user-provided data in the table, the second argument of `pg_extension_config_dump` provides a `WHERE` condition that selects the data to be dumped. For example, you might do

```
CREATE TABLE my_config (key text, value text, standard_entry boolean);

SELECT pg_catalog.pg_extension_config_dump('my_config', 'WHERE NOT standard_entry');
```

and then make sure that `standard_entry` is true only in the rows created by the extension's script.

More complicated situations, such as initially-provided rows that might be modified by users, can be handled by creating triggers on the configuration table to ensure that modified rows are marked correctly.

You can alter the filter condition associated with a configuration table by calling `pg_extension_config_dump` again. (This would typically be useful in an extension update script.) The only way to mark a table as no longer a configuration table is to dissociate it from the extension with `ALTER EXTENSION ... DROP TABLE`.

35.15.4. Extension Updates

One advantage of the extension mechanism is that it provides convenient ways to manage updates to the SQL commands that define an extension's objects. This is done by associating a version name or number with each released version of the extension's installation script. In addition, if you want

users to be able to update their databases dynamically from one version to the next, you should provide *update scripts* that make the necessary changes to go from one version to the next. Update scripts have names following the pattern *extension*--*oldversion*--*newversion*.sql (for example, foo--1.0--1.1.sql contains the commands to modify version 1.0 of extension foo into version 1.1).

Given that a suitable update script is available, the command ALTER EXTENSION UPDATE will update an installed extension to the specified new version. The update script is run in the same environment that CREATE EXTENSION provides for installation scripts: in particular, search_path is set up in the same way, and any new objects created by the script are automatically added to the extension.

If an extension has secondary control files, the control parameters that are used for an update script are those associated with the script's target (new) version.

The update mechanism can be used to solve an important special case: converting a "loose" collection of objects into an extension. Before the extension mechanism was added to PostgreSQL (in 9.1), many people wrote extension modules that simply created assorted unpackaged objects. Given an existing database containing such objects, how can we convert the objects into a properly packaged extension? Dropping them and then doing a plain CREATE EXTENSION is one way, but it's not desirable if the objects have dependencies (for example, if there are table columns of a data type created by the extension). The way to fix this situation is to create an empty extension, then use ALTER EXTENSION ADD to attach each pre-existing object to the extension, then finally create any new objects that are in the current extension version but were not in the unpackaged release. CREATE EXTENSION supports this case with its FROM *old_version* option, which causes it to not run the normal installation script for the target version, but instead the update script named *extension*--*old_version*--*target_version*.sql. The choice of the dummy version name to use as *old_version* is up to the extension author, though unpackaged is a common convention. If you have multiple prior versions you need to be able to update into extension style, use multiple dummy version names to identify them.

ALTER EXTENSION is able to execute sequences of update script files to achieve a requested update. For example, if only foo--1.0--1.1.sql and foo--1.1--2.0.sql are available, ALTER EXTENSION will apply them in sequence if an update to version 2.0 is requested when 1.0 is currently installed.

PostgreSQL doesn't assume anything about the properties of version names: for example, it does not know whether 1.1 follows 1.0. It just matches up the available version names and follows the path that requires applying the fewest update scripts. (A version name can actually be any string that doesn't contain -- or leading or trailing -.)

Sometimes it is useful to provide "downgrade" scripts, for example foo--1.1--1.0.sql to allow reverting the changes associated with version 1.1. If you do that, be careful of the possibility that a downgrade script might unexpectedly get applied because it yields a shorter path. The risky case is where there is a "fast path" update script that jumps ahead several versions as well as a downgrade script to the fast path's start point. It might take fewer steps to apply the downgrade and then the fast path than to move ahead one version at a time. If the downgrade script drops any irreplaceable objects, this will yield undesirable results.

To check for unexpected update paths, use this command:

```
SELECT * FROM pg_extension_update_paths('extension_name');
```

This shows each pair of distinct known version names for the specified extension, together with the update path sequence that would be taken to get from the source version to the target version, or NULL if there is no available update path. The path is shown in textual form with -- separators. You can use regexp_split_to_array(path,'--') if you prefer an array format.

35.15.5. Extension Example

Here is a complete example of an SQL-only extension, a two-element composite type that can store any type of value in its slots, which are named “k” and “v”. Non-text values are automatically coerced to text for storage.

The script file `pair--1.0.sql` looks like this:

```
-- complain if script is sourced in psql, rather than via CREATE EXTENSION
\echo Use "CREATE EXTENSION pair" to load this file. \quit

CREATE TYPE pair AS ( k text, v text );

CREATE OR REPLACE FUNCTION pair(anyelement, text)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1, $2)::pair';

CREATE OR REPLACE FUNCTION pair(text, anyelement)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1, $2)::pair';

CREATE OR REPLACE FUNCTION pair(anyelement, anyelement)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1, $2)::pair';

CREATE OR REPLACE FUNCTION pair(text, text)
RETURNS pair LANGUAGE SQL AS 'SELECT ROW($1, $2)::pair;';

CREATE OPERATOR ~> (LEFTARG = text, RIGHTARG = anyelement, PROCEDURE = pair);
CREATE OPERATOR ~> (LEFTARG = anyelement, RIGHTARG = text, PROCEDURE = pair);
CREATE OPERATOR ~> (LEFTARG = anyelement, RIGHTARG = anyelement, PROCEDURE = pair);
CREATE OPERATOR ~> (LEFTARG = text, RIGHTARG = text, PROCEDURE = pair);
```

The control file `pair.control` looks like this:

```
# pair extension
comment = 'A key/value pair data type'
default_version = '1.0'
relocatable = true
```

While you hardly need a makefile to install these two files into the correct directory, you could use a `Makefile` containing this:

```
EXTENSION = pair
DATA = pair--1.0.sql

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

This makefile relies on PGXS, which is described in Section 35.16. The command `make install` will install the control and script files into the correct directory as reported by pg_config.

Once the files are installed, use the CREATE EXTENSION command to load the objects into any particular database.

35.16. Extension Building Infrastructure

If you are thinking about distributing your PostgreSQL extension modules, setting up a portable build system for them can be fairly difficult. Therefore the PostgreSQL installation provides a build infrastructure for extensions, called PGXS, so that simple extension modules can be built simply against an already installed server. PGXS is mainly intended for extensions that include C code, although it can be used for pure-SQL extensions too. Note that PGXS is not intended to be a universal build system framework that can be used to build any software interfacing to PostgreSQL; it simply automates common build rules for simple server extension modules. For more complicated packages, you might need to write your own build system.

To use the PGXS infrastructure for your extension, you must write a simple makefile. In the makefile, you need to set some variables and include the global PGXS makefile. Here is an example that builds an extension module named `isbn_issn`, consisting of a shared library containing some C code, an extension control file, a SQL script, and a documentation text file:

```
MODULES = isbn_issn
EXTENSION = isbn_issn
DATA = isbn_issn--1.0.sql
DOCS = README.isbn_issn

PG_CONFIG = pg_config
PGXS := $(shell $(PG_CONFIG) --pgxs)
include $(PGXS)
```

The last three lines should always be the same. Earlier in the file, you assign variables or add custom make rules.

Set one of these three variables to specify what is built:

`MODULES`

list of shared-library objects to be built from source files with same stem (do not include library suffixes in this list)

`MODULE_big`

a shared library to build from multiple source files (list object files in `OBJS`)

`PROGRAM`

an executable program to build (list object files in `OBJS`)

The following variables can also be set:

`EXTENSION`

extension name(s); for each name you must provide an *`extension`*`.control` file, which will be installed into *`prefix`*`/share/extension`

`MODULEDIR`

subdirectory of *`prefix`*`/share` into which DATA and DOCS files should be installed (if not set, default is `extension` if `EXTENSION` is set, or `contrib` if not)

`DATA`

random files to install into *`prefix`*`/share/$MODULEDIR`

`DATA_built`

random files to install into *`prefix`*`/share/$MODULEDIR`, which need to be built first

DATA_TSEARCH

random files to install under *prefix*/share/tsearch_data

DOCS

random files to install under *prefix*/doc/$MODULEDIR

SCRIPTS

script files (not binaries) to install into *prefix*/bin

SCRIPTS_built

script files (not binaries) to install into *prefix*/bin, which need to be built first

REGRESS

list of regression test cases (without suffix), see below

REGRESS_OPTS

additional switches to pass to pg_regress

EXTRA_CLEAN

extra files to remove in make clean

PG_CPPFLAGS

will be added to CPPFLAGS

PG_LIBS

will be added to PROGRAM link line

SHLIB_LINK

will be added to MODULE_big link line

PG_CONFIG

path to pg_config program for the PostgreSQL installation to build against (typically just pg_config to use the first one in your PATH)

Put this makefile as Makefile in the directory which holds your extension. Then you can do make to compile, and then make install to install your module. By default, the extension is compiled and installed for the PostgreSQL installation that corresponds to the first pg_config program found in your PATH. You can use a different installation by setting PG_CONFIG to point to its pg_config program, either within the makefile or on the make command line.

You can also run make in a directory outside the source tree of your extension, if you want to keep the build directory separate. This procedure is also called a *VPATH* build. Here's how:

```
mkdir build_dir
cd build_dir
make -f /path/to/extension/source/tree/Makefile
make -f /path/to/extension/source/tree/Makefile install
```

Alternatively, you can set up a directory for a VPATH build in a similar way to how it is done for the core code. One way to do this is using the core script config/prep_buildtree. Once this has been done you can build by setting the make variable VPATH like this:

```
make VPATH=/path/to/extension/source/tree
```

```
make VPATH=/path/to/extension/source/tree install
```

This procedure can work with a greater variety of directory layouts.

The scripts listed in the `REGRESS` variable are used for regression testing of your module, which can be invoked by `make installcheck` after doing `make install`. For this to work you must have a running PostgreSQL server. The script files listed in `REGRESS` must appear in a subdirectory named `sql/` in your extension's directory. These files must have extension `.sql`, which must not be included in the `REGRESS` list in the makefile. For each test there should also be a file containing the expected output in a subdirectory named `expected/`, with the same stem and extension `.out`. `make installcheck` executes each test script with psql, and compares the resulting output to the matching expected file. Any differences will be written to the file `regression.diffs` in `diff -c` format. Note that trying to run a test that is missing its expected file will be reported as "trouble", so make sure you have all expected files.

> **Tip:** The easiest way to create the expected files is to create empty files, then do a test run (which will of course report differences). Inspect the actual result files found in the `results/` directory, then copy them to `expected/` if they match what you expect from the test.

Chapter 36. Triggers

This chapter provides general information about writing trigger functions. Trigger functions can be written in most of the available procedural languages, including PL/pgSQL (Chapter 40), PL/Tcl (Chapter 41), PL/Perl (Chapter 42), and PL/Python (Chapter 43). After reading this chapter, you should consult the chapter for your favorite procedural language to find out the language-specific details of writing a trigger in it.

It is also possible to write a trigger function in C, although most people find it easier to use one of the procedural languages. It is not currently possible to write a trigger function in the plain SQL function language.

36.1. Overview of Trigger Behavior

A trigger is a specification that the database should automatically execute a particular function whenever a certain type of operation is performed. Triggers can be attached to tables, views, and foreign tables.

On tables and foreign tables, triggers can be defined to execute either before or after any `INSERT`, `UPDATE`, or `DELETE` operation, either once per modified row, or once per SQL statement. `UPDATE` triggers can moreover be set to fire only if certain columns are mentioned in the `SET` clause of the `UPDATE` statement. Triggers can also fire for `TRUNCATE` statements. If a trigger event occurs, the trigger's function is called at the appropriate time to handle the event. Foreign tables do not support the TRUNCATE statement at all.

On views, triggers can be defined to execute instead of `INSERT`, `UPDATE`, or `DELETE` operations. `INSTEAD OF` triggers are fired once for each row that needs to be modified in the view. It is the responsibility of the trigger's function to perform the necessary modifications to the underlying base tables and, where appropriate, return the modified row as it will appear in the view. Triggers on views can also be defined to execute once per SQL statement, before or after `INSERT`, `UPDATE`, or `DELETE` operations.

The trigger function must be defined before the trigger itself can be created. The trigger function must be declared as a function taking no arguments and returning type `trigger`. (The trigger function receives its input through a specially-passed `TriggerData` structure, not in the form of ordinary function arguments.)

Once a suitable trigger function has been created, the trigger is established with CREATE TRIGGER. The same trigger function can be used for multiple triggers.

PostgreSQL offers both *per-row* triggers and *per-statement* triggers. With a per-row trigger, the trigger function is invoked once for each row that is affected by the statement that fired the trigger. In contrast, a per-statement trigger is invoked only once when an appropriate statement is executed, regardless of the number of rows affected by that statement. In particular, a statement that affects zero rows will still result in the execution of any applicable per-statement triggers. These two types of triggers are sometimes called *row-level* triggers and *statement-level* triggers, respectively. Triggers on `TRUNCATE` may only be defined at statement level. On views, triggers that fire before or after may only be defined at statement level, while triggers that fire instead of an `INSERT`, `UPDATE`, or `DELETE` may only be defined at row level.

Triggers are also classified according to whether they fire *before*, *after*, or *instead of* the operation. These are referred to as `BEFORE` triggers, `AFTER` triggers, and `INSTEAD OF` triggers respectively. Statement-level `BEFORE` triggers naturally fire before the statement starts to do anything, while statement-level `AFTER` triggers fire at the very end of the statement. These types of triggers may be

defined on tables or views. Row-level BEFORE triggers fire immediately before a particular row is operated on, while row-level AFTER triggers fire at the end of the statement (but before any statement-level AFTER triggers). These types of triggers may only be defined on tables and foreign tables. Row-level INSTEAD OF triggers may only be defined on views, and fire immediately as each row in the view is identified as needing to be operated on.

Trigger functions invoked by per-statement triggers should always return NULL. Trigger functions invoked by per-row triggers can return a table row (a value of type HeapTuple) to the calling executor, if they choose. A row-level trigger fired before an operation has the following choices:

- It can return NULL to skip the operation for the current row. This instructs the executor to not perform the row-level operation that invoked the trigger (the insertion, modification, or deletion of a particular table row).
- For row-level INSERT and UPDATE triggers only, the returned row becomes the row that will be inserted or will replace the row being updated. This allows the trigger function to modify the row being inserted or updated.

A row-level BEFORE trigger that does not intend to cause either of these behaviors must be careful to return as its result the same row that was passed in (that is, the NEW row for INSERT and UPDATE triggers, the OLD row for DELETE triggers).

A row-level INSTEAD OF trigger should either return NULL to indicate that it did not modify any data from the view's underlying base tables, or it should return the view row that was passed in (the NEW row for INSERT and UPDATE operations, or the OLD row for DELETE operations). A nonnull return value is used to signal that the trigger performed the necessary data modifications in the view. This will cause the count of the number of rows affected by the command to be incremented. For INSERT and UPDATE operations, the trigger may modify the NEW row before returning it. This will change the data returned by INSERT RETURNING or UPDATE RETURNING, and is useful when the view will not show exactly the same data that was provided.

The return value is ignored for row-level triggers fired after an operation, and so they can return NULL.

If more than one trigger is defined for the same event on the same relation, the triggers will be fired in alphabetical order by trigger name. In the case of BEFORE and INSTEAD OF triggers, the possibly-modified row returned by each trigger becomes the input to the next trigger. If any BEFORE or INSTEAD OF trigger returns NULL, the operation is abandoned for that row and subsequent triggers are not fired (for that row).

A trigger definition can also specify a Boolean WHEN condition, which will be tested to see whether the trigger should be fired. In row-level triggers the WHEN condition can examine the old and/or new values of columns of the row. (Statement-level triggers can also have WHEN conditions, although the feature is not so useful for them.) In a BEFORE trigger, the WHEN condition is evaluated just before the function is or would be executed, so using WHEN is not materially different from testing the same condition at the beginning of the trigger function. However, in an AFTER trigger, the WHEN condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an AFTER trigger's WHEN condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows. INSTEAD OF triggers do not support WHEN conditions.

Typically, row-level BEFORE triggers are used for checking or modifying the data that will be inserted or updated. For example, a BEFORE trigger might be used to insert the current time into a timestamp column, or to check that two elements of the row are consistent. Row-level AFTER triggers are most sensibly used to propagate the updates to other tables, or make consistency checks against other tables. The reason for this division of labor is that an AFTER trigger can be certain it is seeing the final value

of the row, while a BEFORE trigger cannot; there might be other BEFORE triggers firing after it. If you have no specific reason to make a trigger BEFORE or AFTER, the BEFORE case is more efficient, since the information about the operation doesn't have to be saved until end of statement.

If a trigger function executes SQL commands then these commands might fire triggers again. This is known as cascading triggers. There is no direct limitation on the number of cascade levels. It is possible for cascades to cause a recursive invocation of the same trigger; for example, an INSERT trigger might execute a command that inserts an additional row into the same table, causing the INSERT trigger to be fired again. It is the trigger programmer's responsibility to avoid infinite recursion in such scenarios.

When a trigger is being defined, arguments can be specified for it. The purpose of including arguments in the trigger definition is to allow different triggers with similar requirements to call the same function. As an example, there could be a generalized trigger function that takes as its arguments two column names and puts the current user in one and the current time stamp in the other. Properly written, this trigger function would be independent of the specific table it is triggering on. So the same function could be used for INSERT events on any table with suitable columns, to automatically track creation of records in a transaction table for example. It could also be used to track last-update events if defined as an UPDATE trigger.

Each programming language that supports triggers has its own method for making the trigger input data available to the trigger function. This input data includes the type of trigger event (e.g., INSERT or UPDATE) as well as any arguments that were listed in CREATE TRIGGER. For a row-level trigger, the input data also includes the NEW row for INSERT and UPDATE triggers, and/or the OLD row for UPDATE and DELETE triggers. Statement-level triggers do not currently have any way to examine the individual row(s) modified by the statement.

36.2. Visibility of Data Changes

If you execute SQL commands in your trigger function, and these commands access the table that the trigger is for, then you need to be aware of the data visibility rules, because they determine whether these SQL commands will see the data change that the trigger is fired for. Briefly:

- Statement-level triggers follow simple visibility rules: none of the changes made by a statement are visible to statement-level triggers that are invoked before the statement, whereas all modifications are visible to statement-level AFTER triggers.
- The data change (insertion, update, or deletion) causing the trigger to fire is naturally *not* visible to SQL commands executed in a row-level BEFORE trigger, because it hasn't happened yet.
- However, SQL commands executed in a row-level BEFORE trigger *will* see the effects of data changes for rows previously processed in the same outer command. This requires caution, since the ordering of these change events is not in general predictable; a SQL command that affects multiple rows can visit the rows in any order.
- Similarly, a row-level INSTEAD OF trigger will see the effects of data changes made by previous firings of INSTEAD OF triggers in the same outer command.
- When a row-level AFTER trigger is fired, all data changes made by the outer command are already complete, and are visible to the invoked trigger function.

If your trigger function is written in any of the standard procedural languages, then the above statements apply only if the function is declared VOLATILE. Functions that are declared STABLE or IMMUTABLE will not see changes made by the calling command in any case.

Further information about data visibility rules can be found in Section 44.4. The example in Section 36.4 contains a demonstration of these rules.

36.3. Writing Trigger Functions in C

This section describes the low-level details of the interface to a trigger function. This information is only needed when writing trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your triggers in C. The documentation of each procedural language explains how to write a trigger in that language.

Trigger functions must use the "version 1" function manager interface.

When a function is called by the trigger manager, it is not passed any normal arguments, but it is passed a "context" pointer pointing to a TriggerData structure. C functions can check whether they were called from the trigger manager or not by executing the macro:

```
CALLED_AS_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context, TriggerData))
```

If this returns true, then it is safe to cast fcinfo->context to type TriggerData * and make use of the pointed-to TriggerData structure. The function must *not* alter the TriggerData structure or any of the data it points to.

struct TriggerData is defined in commands/trigger.h:

```
typedef struct TriggerData
{
    NodeTag       type;
    TriggerEvent  tg_event;
    Relation      tg_relation;
    HeapTuple     tg_trigtuple;
    HeapTuple     tg_newtuple;
    Trigger      *tg_trigger;
    Buffer        tg_trigtuplebuf;
    Buffer        tg_newtuplebuf;
} TriggerData;
```

where the members are defined as follows:

type

Always T_TriggerData.

`tg_event`

Describes the event for which the function is called. You can use the following macros to examine `tg_event`:

`TRIGGER_FIRED_BEFORE(tg_event)`

Returns true if the trigger fired before the operation.

`TRIGGER_FIRED_AFTER(tg_event)`

Returns true if the trigger fired after the operation.

`TRIGGER_FIRED_INSTEAD(tg_event)`

Returns true if the trigger fired instead of the operation.

`TRIGGER_FIRED_FOR_ROW(tg_event)`

Returns true if the trigger fired for a row-level event.

`TRIGGER_FIRED_FOR_STATEMENT(tg_event)`

Returns true if the trigger fired for a statement-level event.

`TRIGGER_FIRED_BY_INSERT(tg_event)`

Returns true if the trigger was fired by an `INSERT` command.

`TRIGGER_FIRED_BY_UPDATE(tg_event)`

Returns true if the trigger was fired by an `UPDATE` command.

`TRIGGER_FIRED_BY_DELETE(tg_event)`

Returns true if the trigger was fired by a `DELETE` command.

`TRIGGER_FIRED_BY_TRUNCATE(tg_event)`

Returns true if the trigger was fired by a `TRUNCATE` command.

`tg_relation`

A pointer to a structure describing the relation that the trigger fired for. Look at `utils/rel.h` for details about this structure. The most interesting things are `tg_relation->rd_att` (descriptor of the relation tuples) and `tg_relation->rd_rel->relname` (relation name; the type is not `char*` but `NameData`; use `SPI_getrelname(tg_relation)` to get a `char*` if you need a copy of the name).

`tg_trigtuple`

A pointer to the row for which the trigger was fired. This is the row being inserted, updated, or deleted. If this trigger was fired for an `INSERT` or `DELETE` then this is what you should return from the function if you don't want to replace the row with a different one (in the case of `INSERT`) or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_newtuple`

A pointer to the new version of the row, if the trigger was fired for an `UPDATE`, and `NULL` if it is for an `INSERT` or a `DELETE`. This is what you have to return from the function if the event is an `UPDATE` and you don't want to replace this row by a different one or skip the operation. For triggers on foreign tables, values of system columns herein are unspecified.

`tg_trigger`

A pointer to a structure of type `Trigger`, defined in `utils/reltrigger.h`:

```
typedef struct Trigger
{
    Oid         tgoid;
    char       *tgname;
    Oid         tgfoid;
    int16       tgtype;
    char        tgenabled;
    bool        tgisinternal;
    Oid         tgconstrrelid;
    Oid         tgconstrindid;
    Oid         tgconstraint;
    bool        tgdeferrable;
    bool        tginitdeferred;
    int16       tgnargs;
    int16       tgnattr;
    int16      *tgattr;
    char      **tgargs;
    char       *tgqual;
} Trigger;
```

where `tgname` is the trigger's name, `tgnargs` is the number of arguments in `tgargs`, and `tgargs` is an array of pointers to the arguments specified in the `CREATE TRIGGER` statement. The other members are for internal use only.

`tg_trigtuplebuf`

The buffer containing `tg_trigtuple`, or `InvalidBuffer` if there is no such tuple or it is not stored in a disk buffer.

`tg_newtuplebuf`

The buffer containing `tg_newtuple`, or `InvalidBuffer` if there is no such tuple or it is not stored in a disk buffer.

A trigger function must return either a `HeapTuple` pointer or a `NULL` pointer (*not* an SQL null value, that is, do not set `isNull` true). Be careful to return either `tg_trigtuple` or `tg_newtuple`, as appropriate, if you don't want to modify the row being operated on.

36.4. A Complete Trigger Example

Here is a very simple example of a trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `trigf` reports the number of rows in the table `ttest` and skips the actual operation if the command attempts to insert a null value into the column `x`. (So the trigger acts as a not-null constraint but doesn't abort the transaction.)

First, the table definition:

```
CREATE TABLE ttest (
    x integer
);
```

This is the source code of the trigger function:

```
#include "postgres.h"
#include "executor/spi.h"       /* this is what you need to work with SPI */
#include "commands/trigger.h"   /* ... triggers ... */
#include "utils/rel.h"          /* ... and relations */

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif

extern Datum trigf(PG_FUNCTION_ARGS);

PG_FUNCTION_INFO_V1(trigf);

Datum
trigf(PG_FUNCTION_ARGS)
{
    TriggerData *trigdata = (TriggerData *) fcinfo->context;
    TupleDesc   tupdesc;
    HeapTuple   rettuple;
    char       *when;
    bool        checknull = false;
    bool        isnull;
    int         ret, i;

    /* make sure it's called as a trigger at all */
    if (!CALLED_AS_TRIGGER(fcinfo))
        elog(ERROR, "trigf: not called by trigger manager");

    /* tuple to return to executor */
    if (TRIGGER_FIRED_BY_UPDATE(trigdata->tg_event))
        rettuple = trigdata->tg_newtuple;
    else
        rettuple = trigdata->tg_trigtuple;

    /* check for null values */
    if (!TRIGGER_FIRED_BY_DELETE(trigdata->tg_event)
        && TRIGGER_FIRED_BEFORE(trigdata->tg_event))
        checknull = true;

    if (TRIGGER_FIRED_BEFORE(trigdata->tg_event))
        when = "before";
    else
        when = "after ";

    tupdesc = trigdata->tg_relation->rd_att;

    /* connect to SPI manager */
    if ((ret = SPI_connect()) < 0)
        elog(ERROR, "trigf (fired %s): SPI_connect returned %d", when, ret);

    /* get number of rows in table */
    ret = SPI_exec("SELECT count(*) FROM ttest", 0);

    if (ret < 0)
        elog(ERROR, "trigf (fired %s): SPI_exec returned %d", when, ret);
```

```
    /* count(*) returns int8, so be careful to convert */
    i = DatumGetInt64(SPI_getbinval(SPI_tuptable->vals[0],
                                    SPI_tuptable->tupdesc,
                                    1,
                                    &isnull));

    elog (INFO, "trigf (fired %s): there are %d rows in ttest", when, i);

    SPI_finish();

    if (checknull)
    {
        SPI_getbinval(rettuple, tupdesc, 1, &isnull);
        if (isnull)
            rettuple = NULL;
    }

    return PointerGetDatum(rettuple);
}
```

After you have compiled the source code (see Section 35.9.6), declare the function and the triggers:

```
CREATE FUNCTION trigf() RETURNS trigger
    AS 'filename'
    LANGUAGE C;

CREATE TRIGGER tbefore BEFORE INSERT OR UPDATE OR DELETE ON ttest
    FOR EACH ROW EXECUTE PROCEDURE trigf();

CREATE TRIGGER tafter AFTER INSERT OR UPDATE OR DELETE ON ttest
    FOR EACH ROW EXECUTE PROCEDURE trigf();
```

Now you can test the operation of the trigger:

```
=> INSERT INTO ttest VALUES (NULL);
INFO:  trigf (fired before): there are 0 rows in ttest
INSERT 0 0

-- Insertion skipped and AFTER trigger is not fired

=> SELECT * FROM ttest;
 x
---
(0 rows)

=> INSERT INTO ttest VALUES (1);
INFO:  trigf (fired before): there are 0 rows in ttest
INFO:  trigf (fired after ): there are 1 rows in ttest
                                       ^^^^^^^^
                             remember what we said about visibility.
INSERT 167793 1
vac=> SELECT * FROM ttest;
 x
---
```

```
 1
(1 row)

=> INSERT INTO ttest SELECT x * 2 FROM ttest;
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ): there are 2 rows in ttest
                                       ^^^^^^
                               remember what we said about visibility.
INSERT 167794 1
=> SELECT * FROM ttest;
 x
---
 1
 2
(2 rows)

=> UPDATE ttest SET x = NULL WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
UPDATE 0
=> UPDATE ttest SET x = 4 WHERE x = 2;
INFO:  trigf (fired before): there are 2 rows in ttest
INFO:  trigf (fired after ): there are 2 rows in ttest
UPDATE 1
vac=> SELECT * FROM ttest;
 x
---
 1
 4
(2 rows)

=> DELETE FROM ttest;
INFO:  trigf (fired before): there are 2 rows in ttest
INFO:  trigf (fired before): there are 1 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
INFO:  trigf (fired after ): there are 0 rows in ttest
                                       ^^^^^^
                               remember what we said about visibility.
DELETE 2
=> SELECT * FROM ttest;
 x
---
(0 rows)
```

There are more complex examples in `src/test/regress/regress.c` and in spi.

Chapter 37. Event Triggers

To supplement the trigger mechanism discussed in Chapter 36, PostgreSQL also provides event triggers. Unlike regular triggers, which are attached to a single table and capture only DML events, event triggers are global to a particular database and are capable of capturing DDL events.

Like regular triggers, event triggers can be written in any procedural language that includes event trigger support, or in C, but not in plain SQL.

37.1. Overview of Event Trigger Behavior

An event trigger fires whenever the event with which it is associated occurs in the database in which it is defined. Currently, the only supported events are `ddl_command_start`, `ddl_command_end` and `sql_drop`. Support for additional events may be added in future releases.

The `ddl_command_start` event occurs just before the execution of a `CREATE`, `ALTER`, or `DROP` command. No check whether the affected object exists or doesn't exist is performed before the event trigger fires. As an exception, however, this event does not occur for DDL commands targeting shared objects — databases, roles, and tablespaces — or for commands targeting event triggers themselves. The event trigger mechanism does not support these object types. `ddl_command_start` also occurs just before the execution of a `SELECT INTO` command, since this is equivalent to `CREATE TABLE AS`.

The `ddl_command_end` event occurs just after the execution of this same set of commands.

The `sql_drop` event occurs just before the `ddl_command_end` event trigger for any operation that drops database objects. To list the objects that have been dropped, use the set-returning function `pg_event_trigger_dropped_objects()` from the `sql_drop` event trigger code (see Section 9.28). Note that the trigger is executed after the objects have been deleted from the system catalogs, so it's not possible to look them up anymore.

Event triggers (like other functions) cannot be executed in an aborted transaction. Thus, if a DDL command fails with an error, any associated `ddl_command_end` triggers will not be executed. Conversely, if a `ddl_command_start` trigger fails with an error, no further event triggers will fire, and no attempt will be made to execute the command itself. Similarly, if a `ddl_command_end` trigger fails with an error, the effects of the DDL statement will be rolled back, just as they would be in any other case where the containing transaction aborts.

For a complete list of commands supported by the event trigger mechanism, see Section 37.2.

Event triggers are created using the command CREATE EVENT TRIGGER. In order to create an event trigger, you must first create a function with the special return type `event_trigger`. This function need not (and may not) return a value; the return type serves merely as a signal that the function is to be invoked as an event trigger.

If more than one event trigger is defined for a particular event, they will fire in alphabetical order by trigger name.

A trigger definition can also specify a `WHEN` condition so that, for example, a `ddl_command_start` trigger can be fired only for particular commands which the user wishes to intercept. A common use of such triggers is to restrict the range of DDL operations which users may perform.

37.2. Event Trigger Firing Matrix

Table 37-1 lists all commands for which event triggers are supported.

Table 37-1. Event Trigger Support by Command Tag

command tag	ddl_command_start	ddl_command_end	sql_drop
ALTER AGGREGATE	X	X	-
ALTER COLLATION	X	X	-
ALTER CONVERSION	X	X	-
ALTER DOMAIN	X	X	-
ALTER EXTENSION	X	X	-
ALTER FOREIGN DATA WRAPPER	X	X	-
ALTER FOREIGN TABLE	X	X	X
ALTER FUNCTION	X	X	-
ALTER LANGUAGE	X	X	-
ALTER OPERATOR	X	X	-
ALTER OPERATOR CLASS	X	X	-
ALTER OPERATOR FAMILY	X	X	-
ALTER SCHEMA	X	X	-
ALTER SEQUENCE	X	X	-
ALTER SERVER	X	X	-
ALTER TABLE	X	X	X
ALTER TEXT SEARCH CONFIGURATION	X	X	-
ALTER TEXT SEARCH DICTIONARY	X	X	-
ALTER TEXT SEARCH PARSER	X	X	-
ALTER TEXT SEARCH TEMPLATE	X	X	-
ALTER TRIGGER	X	X	-
ALTER TYPE	X	X	-
ALTER USER MAPPING	X	X	-
ALTER VIEW	X	X	-
CREATE AGGREGATE	X	X	-
CREATE CAST	X	X	-
CREATE COLLATION	X	X	-
CREATE CONVERSION	X	X	-
CREATE DOMAIN	X	X	-

command tag	ddl_command_start	ddl_command_end	sql_drop
CREATE EXTENSION	X	X	-
CREATE FOREIGN DATA WRAPPER	X	X	-
CREATE FOREIGN TABLE	X	X	-
CREATE FUNCTION	X	X	-
CREATE INDEX	X	X	-
CREATE LANGUAGE	X	X	-
CREATE OPERATOR	X	X	-
CREATE OPERATOR CLASS	X	X	-
CREATE OPERATOR FAMILY	X	X	-
CREATE RULE	X	X	-
CREATE SCHEMA	X	X	-
CREATE SEQUENCE	X	X	-
CREATE SERVER	X	X	-
CREATE TABLE	X	X	-
CREATE TABLE AS	X	X	-
CREATE TEXT SEARCH CONFIGURATION	X	X	-
CREATE TEXT SEARCH DICTIONARY	X	X	-
CREATE TEXT SEARCH PARSER	X	X	-
CREATE TEXT SEARCH TEMPLATE	X	X	-
CREATE TRIGGER	X	X	-
CREATE TYPE	X	X	-
CREATE USER MAPPING	X	X	-
CREATE VIEW	X	X	-
DROP AGGREGATE	X	X	X
DROP CAST	X	X	X
DROP COLLATION	X	X	X
DROP CONVERSION	X	X	X
DROP DOMAIN	X	X	X
DROP EXTENSION	X	X	X
DROP FOREIGN DATA WRAPPER	X	X	X
DROP FOREIGN TABLE	X	X	X
DROP FUNCTION	X	X	X

command tag	ddl_command_start	ddl_command_end	sql_drop
DROP INDEX	X	X	X
DROP LANGUAGE	X	X	X
DROP OPERATOR	X	X	X
DROP OPERATOR CLASS	X	X	X
DROP OPERATOR FAMILY	X	X	X
DROP OWNED	X	X	X
DROP RULE	X	X	X
DROP SCHEMA	X	X	X
DROP SEQUENCE	X	X	X
DROP SERVER	X	X	X
DROP TABLE	X	X	X
DROP TEXT SEARCH CONFIGURATION	X	X	X
DROP TEXT SEARCH DICTIONARY	X	X	X
DROP TEXT SEARCH PARSER	X	X	X
DROP TEXT SEARCH TEMPLATE	X	X	X
DROP TRIGGER	X	X	X
DROP TYPE	X	X	X
DROP USER MAPPING	X	X	X
DROP VIEW	X	X	X
SELECT INTO	X	X	-

37.3. Writing Event Trigger Functions in C

This section describes the low-level details of the interface to an event trigger function. This information is only needed when writing event trigger functions in C. If you are using a higher-level language then these details are handled for you. In most cases you should consider using a procedural language before writing your event triggers in C. The documentation of each procedural language explains how to write an event trigger in that language.

Event trigger functions must use the "version 1" function manager interface.

When a function is called by the event trigger manager, it is not passed any normal arguments, but it is passed a "context" pointer pointing to a `EventTriggerData` structure. C functions can check whether they were called from the event trigger manager or not by executing the macro:

```
CALLED_AS_EVENT_TRIGGER(fcinfo)
```

which expands to:

```
((fcinfo)->context != NULL && IsA((fcinfo)->context, EventTriggerData))
```

If this returns true, then it is safe to cast `fcinfo->context` to type `EventTriggerData *` and make use of the pointed-to `EventTriggerData` structure. The function must *not* alter the `EventTriggerData` structure or any of the data it points to.

`struct EventTriggerData` is defined in `commands/event_trigger.h`:

```
typedef struct EventTriggerData
{
    NodeTag     type;
    const char *event;      /* event name */
    Node       *parsetree;  /* parse tree */
    const char *tag;        /* command tag */
} EventTriggerData;
```

where the members are defined as follows:

`type`

Always `T_EventTriggerData`.

`event`

Describes the event for which the function is called, one of `"ddl_command_start"`, `"ddl_command_end"`, `"sql_drop"`. See Section 37.1 for the meaning of these events.

`parsetree`

A pointer to the parse tree of the command. Check the PostgreSQL source code for details. The parse tree structure is subject to change without notice.

`tag`

The command tag associated with the event for which the event trigger is run, for example `"CREATE FUNCTION"`.

An event trigger function must return a `NULL` pointer (*not* an SQL null value, that is, do not set `isNull` true).

37.4. A Complete Event Trigger Example

Here is a very simple example of an event trigger function written in C. (Examples of triggers written in procedural languages can be found in the documentation of the procedural languages.)

The function `noddl` raises an exception each time it is called. The event trigger definition associated the function with the `ddl_command_start` event. The effect is that all DDL commands (with the exceptions mentioned in Section 37.1) are prevented from running.

This is the source code of the trigger function:

```
#include "postgres.h"
#include "commands/event_trigger.h"


PG_MODULE_MAGIC;

Datum noddl(PG_FUNCTION_ARGS);
```

```
PG_FUNCTION_INFO_V1(noddl);

Datum
noddl(PG_FUNCTION_ARGS)
{
    EventTriggerData *trigdata;

    if (!CALLED_AS_EVENT_TRIGGER(fcinfo))  /* internal error */
        elog(ERROR, "not fired by event trigger manager");

    trigdata = (EventTriggerData *) fcinfo->context;

    ereport(ERROR,
        (errcode(ERRCODE_INSUFFICIENT_PRIVILEGE),
                 errmsg("command \"%s\" denied", trigdata->tag)));

    PG_RETURN_NULL();
}
```

After you have compiled the source code (see Section 35.9.6), declare the function and the triggers:

```
CREATE FUNCTION noddl() RETURNS event_trigger
    AS 'noddl' LANGUAGE C;

CREATE EVENT TRIGGER noddl ON ddl_command_start
    EXECUTE PROCEDURE noddl();
```

Now you can test the operation of the trigger:

```
=# \dy
                     List of event triggers
 Name  |       Event       | Owner | Enabled | Procedure | Tags
-------+-------------------+-------+---------+-----------+------
 noddl | ddl_command_start | dim   | enabled | noddl     |
(1 row)

=# CREATE TABLE foo(id serial);
ERROR:  command "CREATE TABLE" denied
```

In this situation, in order to be able to run some DDL commands when you need to do so, you have to either drop the event trigger or disable it. It can be convenient to disable the trigger for only the duration of a transaction:

```
BEGIN;
ALTER EVENT TRIGGER noddl DISABLE;
CREATE TABLE foo (id serial);
ALTER EVENT TRIGGER noddl ENABLE;
COMMIT;
```

(Recall that DDL commands on event triggers themselves are not affected by event triggers.)

Chapter 38. The Rule System

This chapter discusses the rule system in PostgreSQL. Production rule systems are conceptually simple, but there are many subtle points involved in actually using them.

Some other database systems define active database rules, which are usually stored procedures and triggers. In PostgreSQL, these can be implemented using functions and triggers as well.

The rule system (more precisely speaking, the query rewrite rule system) is totally different from stored procedures and triggers. It modifies queries to take rules into consideration, and then passes the modified query to the query planner for planning and execution. It is very powerful, and can be used for many things such as query language procedures, views, and versions. The theoretical foundations and the power of this rule system are also discussed in *On Rules, Procedures, Caching and Views in Database Systems* and *A Unified Framework for Version Modeling Using Production Rules in a Database System*.

38.1. The Query Tree

To understand how the rule system works it is necessary to know when it is invoked and what its input and results are.

The rule system is located between the parser and the planner. It takes the output of the parser, one query tree, and the user-defined rewrite rules, which are also query trees with some extra information, and creates zero or more query trees as result. So its input and output are always things the parser itself could have produced and thus, anything it sees is basically representable as an SQL statement.

Now what is a query tree? It is an internal representation of an SQL statement where the single parts that it is built from are stored separately. These query trees can be shown in the server log if you set the configuration parameters `debug_print_parse`, `debug_print_rewritten`, or `debug_print_plan`. The rule actions are also stored as query trees, in the system catalog `pg_rewrite`. They are not formatted like the log output, but they contain exactly the same information.

Reading a raw query tree requires some experience. But since SQL representations of query trees are sufficient to understand the rule system, this chapter will not teach how to read them.

When reading the SQL representations of the query trees in this chapter it is necessary to be able to identify the parts the statement is broken into when it is in the query tree structure. The parts of a query tree are

the command type

This is a simple value telling which command (`SELECT`, `INSERT`, `UPDATE`, `DELETE`) produced the query tree.

the range table

The range table is a list of relations that are used in the query. In a `SELECT` statement these are the relations given after the `FROM` key word.

Every range table entry identifies a table or view and tells by which name it is called in the other parts of the query. In the query tree, the range table entries are referenced by number rather than by name, so here it doesn't matter if there are duplicate names as it would in an SQL statement. This can happen after the range tables of rules have been merged in. The examples in this chapter will not have this situation.

the result relation

This is an index into the range table that identifies the relation where the results of the query go.

SELECT queries don't have a result relation. (The special case of SELECT INTO is mostly identical to CREATE TABLE followed by INSERT ... SELECT, and is not discussed separately here.)

For INSERT, UPDATE, and DELETE commands, the result relation is the table (or view!) where the changes are to take effect.

the target list

The target list is a list of expressions that define the result of the query. In the case of a SELECT, these expressions are the ones that build the final output of the query. They correspond to the expressions between the key words SELECT and FROM. (* is just an abbreviation for all the column names of a relation. It is expanded by the parser into the individual columns, so the rule system never sees it.)

DELETE commands don't need a normal target list because they don't produce any result. Instead, the rule system adds a special CTID entry to the empty target list, to allow the executor to find the row to be deleted. (CTID is added when the result relation is an ordinary table. If it is a view, a whole-row variable is added instead, as described in Section 38.2.4.)

For INSERT commands, the target list describes the new rows that should go into the result relation. It consists of the expressions in the VALUES clause or the ones from the SELECT clause in INSERT ... SELECT. The first step of the rewrite process adds target list entries for any columns that were not assigned to by the original command but have defaults. Any remaining columns (with neither a given value nor a default) will be filled in by the planner with a constant null expression.

For UPDATE commands, the target list describes the new rows that should replace the old ones. In the rule system, it contains just the expressions from the SET column = expression part of the command. The planner will handle missing columns by inserting expressions that copy the values from the old row into the new one. Just as for DELETE, the rule system adds a CTID or whole-row variable so that the executor can identify the old row to be updated.

Every entry in the target list contains an expression that can be a constant value, a variable pointing to a column of one of the relations in the range table, a parameter, or an expression tree made of function calls, constants, variables, operators, etc.

the qualification

The query's qualification is an expression much like one of those contained in the target list entries. The result value of this expression is a Boolean that tells whether the operation (INSERT, UPDATE, DELETE, or SELECT) for the final result row should be executed or not. It corresponds to the WHERE clause of an SQL statement.

the join tree

The query's join tree shows the structure of the FROM clause. For a simple query like SELECT ... FROM a, b, c, the join tree is just a list of the FROM items, because we are allowed to join them in any order. But when JOIN expressions, particularly outer joins, are used, we have to join in the order shown by the joins. In that case, the join tree shows the structure of the JOIN expressions. The restrictions associated with particular JOIN clauses (from ON or USING expressions) are stored as qualification expressions attached to those join-tree nodes. It turns out to be convenient to store the top-level WHERE expression as a qualification attached to the top-level join-tree item, too. So really the join tree represents both the FROM and WHERE clauses of a SELECT.

the others

The other parts of the query tree like the ORDER BY clause aren't of interest here. The rule system substitutes some entries there while applying rules, but that doesn't have much to do with the fundamentals of the rule system.

38.2. Views and the Rule System

Views in PostgreSQL are implemented using the rule system. In fact, there is essentially no difference between:

```
CREATE VIEW myview AS SELECT * FROM mytab;
```

compared against the two commands:

```
CREATE TABLE myview (same column list as mytab);
CREATE RULE "_RETURN" AS ON SELECT TO myview DO INSTEAD
    SELECT * FROM mytab;
```

because this is exactly what the CREATE VIEW command does internally. This has some side effects. One of them is that the information about a view in the PostgreSQL system catalogs is exactly the same as it is for a table. So for the parser, there is absolutely no difference between a table and a view. They are the same thing: relations.

38.2.1. How SELECT Rules Work

Rules ON SELECT are applied to all queries as the last step, even if the command given is an INSERT, UPDATE or DELETE. And they have different semantics from rules on the other command types in that they modify the query tree in place instead of creating a new one. So SELECT rules are described first.

Currently, there can be only one action in an ON SELECT rule, and it must be an unconditional SELECT action that is INSTEAD. This restriction was required to make rules safe enough to open them for ordinary users, and it restricts ON SELECT rules to act like views.

The examples for this chapter are two join views that do some calculations and some more views using them in turn. One of the two first views is customized later by adding rules for INSERT, UPDATE, and DELETE operations so that the final result will be a view that behaves like a real table with some magic functionality. This is not such a simple example to start from and this makes things harder to get into. But it's better to have one example that covers all the points discussed step by step rather than having many different ones that might mix up in mind.

For the example, we need a little min function that returns the lower of 2 integer values. We create that as:

```
CREATE FUNCTION min(integer, integer) RETURNS integer AS $$
    SELECT CASE WHEN $1 < $2 THEN $1 ELSE $2 END
$$ LANGUAGE SQL STRICT;
```

The real tables we need in the first two rule system descriptions are these:

```
CREATE TABLE shoe_data (
    shoename   text,          -- primary key
```

```
    sh_avail   integer,       -- available number of pairs
    slcolor    text,          -- preferred shoelace color
    slminlen   real,          -- minimum shoelace length
    slmaxlen   real,          -- maximum shoelace length
    slunit     text           -- length unit
);

CREATE TABLE shoelace_data (
    sl_name    text,          -- primary key
    sl_avail   integer,       -- available number of pairs
    sl_color   text,          -- shoelace color
    sl_len     real,          -- shoelace length
    sl_unit    text           -- length unit
);

CREATE TABLE unit (
    un_name    text,          -- primary key
    un_fact    real           -- factor to transform to cm
);
```

As you can see, they represent shoe-store data.

The views are created as:

```
CREATE VIEW shoe AS
    SELECT sh.shoename,
           sh.sh_avail,
           sh.slcolor,
           sh.slminlen,
           sh.slminlen * un.un_fact AS slminlen_cm,
           sh.slmaxlen,
           sh.slmaxlen * un.un_fact AS slmaxlen_cm,
           sh.slunit
      FROM shoe_data sh, unit un
     WHERE sh.slunit = un.un_name;

CREATE VIEW shoelace AS
    SELECT s.sl_name,
           s.sl_avail,
           s.sl_color,
           s.sl_len,
           s.sl_unit,
           s.sl_len * u.un_fact AS sl_len_cm
      FROM shoelace_data s, unit u
     WHERE s.sl_unit = u.un_name;

CREATE VIEW shoe_ready AS
    SELECT rsh.shoename,
           rsh.sh_avail,
           rsl.sl_name,
           rsl.sl_avail,
           min(rsh.sh_avail, rsl.sl_avail) AS total_avail
      FROM shoe rsh, shoelace rsl
     WHERE rsl.sl_color = rsh.slcolor
       AND rsl.sl_len_cm >= rsh.slminlen_cm
       AND rsl.sl_len_cm <= rsh.slmaxlen_cm;
```

The `CREATE VIEW` command for the `shoelace` view (which is the simplest one we have) will create a relation `shoelace` and an entry in `pg_rewrite` that tells that there is a rewrite rule that must be applied whenever the relation `shoelace` is referenced in a query's range table. The rule has no rule qualification (discussed later, with the non-`SELECT` rules, since `SELECT` rules currently cannot have them) and it is `INSTEAD`. Note that rule qualifications are not the same as query qualifications. The action of our rule has a query qualification. The action of the rule is one query tree that is a copy of the `SELECT` statement in the view creation command.

> **Note:** The two extra range table entries for `NEW` and `OLD` that you can see in the `pg_rewrite` entry aren't of interest for `SELECT` rules.

Now we populate `unit`, `shoe_data` and `shoelace_data` and run a simple query on a view:

```
INSERT INTO unit VALUES ('cm', 1.0);
INSERT INTO unit VALUES ('m', 100.0);
INSERT INTO unit VALUES ('inch', 2.54);

INSERT INTO shoe_data VALUES ('sh1', 2, 'black', 70.0, 90.0, 'cm');
INSERT INTO shoe_data VALUES ('sh2', 0, 'black', 30.0, 40.0, 'inch');
INSERT INTO shoe_data VALUES ('sh3', 4, 'brown', 50.0, 65.0, 'cm');
INSERT INTO shoe_data VALUES ('sh4', 3, 'brown', 40.0, 50.0, 'inch');

INSERT INTO shoelace_data VALUES ('sl1', 5, 'black', 80.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl2', 6, 'black', 100.0, 'cm');
INSERT INTO shoelace_data VALUES ('sl3', 0, 'black', 35.0 , 'inch');
INSERT INTO shoelace_data VALUES ('sl4', 8, 'black', 40.0 , 'inch');
INSERT INTO shoelace_data VALUES ('sl5', 4, 'brown', 1.0 , 'm');
INSERT INTO shoelace_data VALUES ('sl6', 0, 'brown', 0.9 , 'm');
INSERT INTO shoelace_data VALUES ('sl7', 7, 'brown', 60 , 'cm');
INSERT INTO shoelace_data VALUES ('sl8', 1, 'brown', 40 , 'inch');

SELECT * FROM shoelace;

 sl_name   | sl_avail | sl_color | sl_len | sl_unit | sl_len_cm
-----------+----------+----------+--------+---------+-----------
 sl1       |        5 | black    |     80 | cm      |        80
 sl2       |        6 | black    |    100 | cm      |       100
 sl7       |        7 | brown    |     60 | cm      |        60
 sl3       |        0 | black    |     35 | inch    |      88.9
 sl4       |        8 | black    |     40 | inch    |     101.6
 sl8       |        1 | brown    |     40 | inch    |     101.6
 sl5       |        4 | brown    |      1 | m       |       100
 sl6       |        0 | brown    |    0.9 | m       |        90
(8 rows)
```

This is the simplest `SELECT` you can do on our views, so we take this opportunity to explain the basics of view rules. The `SELECT * FROM shoelace` was interpreted by the parser and produced the query tree:

```
SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
  FROM shoelace shoelace;
```

and this is given to the rule system. The rule system walks through the range table and checks if there are rules for any relation. When processing the range table entry for `shoelace` (the only one up to now) it finds the `_RETURN` rule with the query tree:

```
SELECT s.sl_name, s.sl_avail,
       s.sl_color, s.sl_len, s.sl_unit,
       s.sl_len * u.un_fact AS sl_len_cm
  FROM shoelace old, shoelace new,
       shoelace_data s, unit u
 WHERE s.sl_unit = u.un_name;
```

To expand the view, the rewriter simply creates a subquery range-table entry containing the rule's action query tree, and substitutes this range table entry for the original one that referenced the view. The resulting rewritten query tree is almost the same as if you had typed:

```
SELECT shoelace.sl_name, shoelace.sl_avail,
       shoelace.sl_color, shoelace.sl_len,
       shoelace.sl_unit, shoelace.sl_len_cm
  FROM (SELECT s.sl_name,
               s.sl_avail,
               s.sl_color,
               s.sl_len,
               s.sl_unit,
               s.sl_len * u.un_fact AS sl_len_cm
          FROM shoelace_data s, unit u
         WHERE s.sl_unit = u.un_name) shoelace;
```

There is one difference however: the subquery's range table has two extra entries `shoelace old` and `shoelace new`. These entries don't participate directly in the query, since they aren't referenced by the subquery's join tree or target list. The rewriter uses them to store the access privilege check information that was originally present in the range-table entry that referenced the view. In this way, the executor will still check that the user has proper privileges to access the view, even though there's no direct use of the view in the rewritten query.

That was the first rule applied. The rule system will continue checking the remaining range-table entries in the top query (in this example there are no more), and it will recursively check the range-table entries in the added subquery to see if any of them reference views. (But it won't expand `old` or `new` — otherwise we'd have infinite recursion!) In this example, there are no rewrite rules for `shoelace_data` or `unit`, so rewriting is complete and the above is the final result given to the planner.

Now we want to write a query that finds out for which shoes currently in the store we have the matching shoelaces (color and length) and where the total number of exactly matching pairs is greater or equal to two.

```
SELECT * FROM shoe_ready WHERE total_avail >= 2;

 shoename | sh_avail | sl_name | sl_avail | total_avail
----------+----------+---------+----------+-------------
 sh1      |        2 | sl1     |        5 |           2
 sh3      |        4 | sl7     |        7 |           4
(2 rows)
```

The output of the parser this time is the query tree:

```
SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
  FROM shoe_ready shoe_ready
 WHERE shoe_ready.total_avail >= 2;
```

The first rule applied will be the one for the `shoe_ready` view and it results in the query tree:

```
SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
  FROM (SELECT rsh.shoename,
               rsh.sh_avail,
               rsl.sl_name,
               rsl.sl_avail,
               min(rsh.sh_avail, rsl.sl_avail) AS total_avail
          FROM shoe rsh, shoelace rsl
         WHERE rsl.sl_color = rsh.slcolor
           AND rsl.sl_len_cm >= rsh.slminlen_cm
           AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
 WHERE shoe_ready.total_avail >= 2;
```

Similarly, the rules for `shoe` and `shoelace` are substituted into the range table of the subquery, leading to a three-level final query tree:

```
SELECT shoe_ready.shoename, shoe_ready.sh_avail,
       shoe_ready.sl_name, shoe_ready.sl_avail,
       shoe_ready.total_avail
  FROM (SELECT rsh.shoename,
               rsh.sh_avail,
               rsl.sl_name,
               rsl.sl_avail,
               min(rsh.sh_avail, rsl.sl_avail) AS total_avail
          FROM (SELECT sh.shoename,
                       sh.sh_avail,
                       sh.slcolor,
                       sh.slminlen,
                       sh.slminlen * un.un_fact AS slminlen_cm,
                       sh.slmaxlen,
                       sh.slmaxlen * un.un_fact AS slmaxlen_cm,
                       sh.slunit
                  FROM shoe_data sh, unit un
                 WHERE sh.slunit = un.un_name) rsh,
               (SELECT s.sl_name,
                       s.sl_avail,
                       s.sl_color,
                       s.sl_len,
                       s.sl_unit,
                       s.sl_len * u.un_fact AS sl_len_cm
                  FROM shoelace_data s, unit u
                 WHERE s.sl_unit = u.un_name) rsl
         WHERE rsl.sl_color = rsh.slcolor
           AND rsl.sl_len_cm >= rsh.slminlen_cm
           AND rsl.sl_len_cm <= rsh.slmaxlen_cm) shoe_ready
 WHERE shoe_ready.total_avail > 2;
```

It turns out that the planner will collapse this tree into a two-level query tree: the bottommost SELECT commands will be "pulled up" into the middle SELECT since there's no need to process them separately. But the middle SELECT will remain separate from the top, because it contains aggregate functions. If we pulled those up it would change the behavior of the topmost SELECT, which we don't want. However, collapsing the query tree is an optimization that the rewrite system doesn't have to concern itself with.

38.2.2. View Rules in Non-SELECT Statements

Two details of the query tree aren't touched in the description of view rules above. These are the command type and the result relation. In fact, the command type is not needed by view rules, but the result relation may affect the way in which the query rewriter works, because special care needs to be taken if the result relation is a view.

There are only a few differences between a query tree for a SELECT and one for any other command. Obviously, they have a different command type and for a command other than a SELECT, the result relation points to the range-table entry where the result should go. Everything else is absolutely the same. So having two tables t1 and t2 with columns a and b, the query trees for the two statements:

```
SELECT t2.b FROM t1, t2 WHERE t1.a = t2.a;

UPDATE t1 SET b = t2.b FROM t2 WHERE t1.a = t2.a;
```

are nearly identical. In particular:

- The range tables contain entries for the tables t1 and t2.
- The target lists contain one variable that points to column b of the range table entry for table t2.
- The qualification expressions compare the columns a of both range-table entries for equality.
- The join trees show a simple join between t1 and t2.

The consequence is, that both query trees result in similar execution plans: They are both joins over the two tables. For the UPDATE the missing columns from t1 are added to the target list by the planner and the final query tree will read as:

```
UPDATE t1 SET a = t1.a, b = t2.b FROM t2 WHERE t1.a = t2.a;
```

and thus the executor run over the join will produce exactly the same result set as:

```
SELECT t1.a, t2.b FROM t1, t2 WHERE t1.a = t2.a;
```

But there is a little problem in UPDATE: the part of the executor plan that does the join does not care what the results from the join are meant for. It just produces a result set of rows. The fact that one is a SELECT command and the other is an UPDATE is handled higher up in the executor, where it knows that this is an UPDATE, and it knows that this result should go into table t1. But which of the rows that are there has to be replaced by the new row?

To resolve this problem, another entry is added to the target list in UPDATE (and also in DELETE) statements: the current tuple ID (CTID). This is a system column containing the file block number and position in the block for the row. Knowing the table, the CTID can be used to retrieve the original row of t1 to be updated. After adding the CTID to the target list, the query actually looks like:

```
SELECT t1.a, t2.b, t1.ctid FROM t1, t2 WHERE t1.a = t2.a;
```

Now another detail of PostgreSQL enters the stage. Old table rows aren't overwritten, and this is why ROLLBACK is fast. In an UPDATE, the new result row is inserted into the table (after stripping the CTID) and in the row header of the old row, which the CTID pointed to, the cmax and xmax entries are set to the current command counter and current transaction ID. Thus the old row is hidden, and after the transaction commits the vacuum cleaner can eventually remove the dead row.

Knowing all that, we can simply apply view rules in absolutely the same way to any command. There is no difference.

38.2.3. The Power of Views in PostgreSQL

The above demonstrates how the rule system incorporates view definitions into the original query tree. In the second example, a simple SELECT from one view created a final query tree that is a join of 4 tables (unit was used twice with different names).

The benefit of implementing views with the rule system is, that the planner has all the information about which tables have to be scanned plus the relationships between these tables plus the restrictive qualifications from the views plus the qualifications from the original query in one single query tree. And this is still the situation when the original query is already a join over views. The planner has to decide which is the best path to execute the query, and the more information the planner has, the better this decision can be. And the rule system as implemented in PostgreSQL ensures, that this is all information available about the query up to that point.

38.2.4. Updating a View

What happens if a view is named as the target relation for an INSERT, UPDATE, or DELETE? Doing the substitutions described above would give a query tree in which the result relation points at a subquery range-table entry, which will not work. There are several ways in which PostgreSQL can support the appearance of updating a view, however.

If the subquery selects from a single base relation and is simple enough, the rewriter can automatically replace the subquery with the underlying base relation so that the INSERT, UPDATE, or DELETE is applied to the base relation in the appropriate way. Views that are "simple enough" for this are called *automatically updatable*. For detailed information on the kinds of view that can be automatically updated, see CREATE VIEW.

Alternatively, the operation may be handled by a user-provided INSTEAD OF trigger on the view. Rewriting works slightly differently in this case. For INSERT, the rewriter does nothing at all with the view, leaving it as the result relation for the query. For UPDATE and DELETE, it's still necessary to expand the view query to produce the "old" rows that the command will attempt to update or delete. So the view is expanded as normal, but another unexpanded range-table entry is added to the query to represent the view in its capacity as the result relation.

The problem that now arises is how to identify the rows to be updated in the view. Recall that when the result relation is a table, a special CTID entry is added to the target list to identify the physical locations of the rows to be updated. This does not work if the result relation is a view, because a view does not have any CTID, since its rows do not have actual physical locations. Instead, for an UPDATE or DELETE operation, a special wholerow entry is added to the target list, which expands to include all columns from the view. The executor uses this value to supply the "old" row to the INSTEAD OF trigger. It is up to the trigger to work out what to update based on the old and new row values.

Another possibility is for the user to define INSTEAD rules that specify substitute actions for INSERT, UPDATE, and DELETE commands on a view. These rules will rewrite the command, typically into a command that updates one or more tables, rather than views. That is the topic of the next section.

Note that rules are evaluated first, rewriting the original query before it is planned and executed. Therefore, if a view has INSTEAD OF triggers as well as rules on INSERT, UPDATE, or DELETE, then the rules will be evaluated first, and depending on the result, the triggers may not be used at all.

Automatic rewriting of an INSERT, UPDATE, or DELETE query on a simple view is always tried last. Therefore, if a view has rules or triggers, they will override the default behavior of automatically updatable views.

If there are no INSTEAD rules or INSTEAD OF triggers for the view, and the rewriter cannot automatically rewrite the query as an update on the underlying base relation, an error will be thrown because the executor cannot update a view as such.

38.3. Materialized Views

Materialized views in PostgreSQL use the rule system like views do, but persist the results in a table-like form. The main differences between:

```
CREATE MATERIALIZED VIEW mymatview AS SELECT * FROM mytab;
```

and:

```
CREATE TABLE mymatview AS SELECT * FROM mytab;
```

are that the materialized view cannot subsequently be directly updated and that the query used to create the materialized view is stored in exactly the same way that a view's query is stored, so that fresh data can be generated for the materialized view with:

```
REFRESH MATERIALIZED VIEW mymatview;
```

The information about a materialized view in the PostgreSQL system catalogs is exactly the same as it is for a table or view. So for the parser, a materialized view is a relation, just like a table or a view. When a materialized view is referenced in a query, the data is returned directly from the materialized view, like from a table; the rule is only used for populating the materialized view.

While access to the data stored in a materialized view is often much faster than accessing the underlying tables directly or through a view, the data is not always current; yet sometimes current data is not needed. Consider a table which records sales:

```
CREATE TABLE invoice (
    invoice_no    integer        PRIMARY KEY,
    seller_no     integer,       -- ID of salesperson
    invoice_date  date,          -- date of sale
    invoice_amt   numeric(13,2)  -- amount of sale
);
```

If people want to be able to quickly graph historical sales data, they might want to summarize, and they may not care about the incomplete data for the current date:

```
CREATE MATERIALIZED VIEW sales_summary AS
  SELECT
      seller_no,
```

```
      invoice_date,
      sum(invoice_amt)::numeric(13,2) as sales_amt
    FROM invoice
    WHERE invoice_date < CURRENT_DATE
    GROUP BY
      seller_no,
      invoice_date
    ORDER BY
      seller_no,
      invoice_date;

CREATE UNIQUE INDEX sales_summary_seller
  ON sales_summary (seller_no, invoice_date);
```

This materialized view might be useful for displaying a graph in the dashboard created for salespeople. A job could be scheduled to update the statistics each night using this SQL statement:

```
REFRESH MATERIALIZED VIEW sales_summary;
```

Another use for a materialized view is to allow faster access to data brought across from a remote system through a foreign data wrapper. A simple example using `file_fdw` is below, with timings, but since this is using cache on the local system the performance difference compared to access to a remote system would usually be greater than shown here. Notice we are also exploiting the ability to put an index on the materialized view, whereas `file_fdw` does not support indexes; this advantage might not apply for other sorts of foreign data access.

Setup:

```
CREATE EXTENSION file_fdw;
CREATE SERVER local_file FOREIGN DATA WRAPPER file_fdw;
CREATE FOREIGN TABLE words (word text NOT NULL)
  SERVER local_file
  OPTIONS (filename '/usr/share/dict/words');
CREATE MATERIALIZED VIEW wrd AS SELECT * FROM words;
CREATE UNIQUE INDEX wrd_word ON wrd (word);
CREATE EXTENSION pg_trgm;
CREATE INDEX wrd_trgm ON wrd USING gist (word gist_trgm_ops);
VACUUM ANALYZE wrd;
```

Now let's spell-check a word. Using `file_fdw` directly:

```
SELECT count(*) FROM words WHERE word = 'caterpiler';

 count
-------
     0
(1 row)
```

With `EXPLAIN ANALYZE`, we see:

```
 Aggregate  (cost=21763.99..21764.00 rows=1 width=0) (actual time=188.180..188.181 rows=
   ->  Foreign Scan on words  (cost=0.00..21761.41 rows=1032 width=0) (actual time=188.1
         Filter: (word = 'caterpiler'::text)
         Rows Removed by Filter: 479829
         Foreign File: /usr/share/dict/words
         Foreign File Size: 4953699
```

```
 Planning time: 0.118 ms
 Execution time: 188.273 ms
```

If the materialized view is used instead, the query is much faster:

```
 Aggregate  (cost=4.44..4.45 rows=1 width=0) (actual time=0.042..0.042 rows=1 loops=1)
   ->  Index Only Scan using wrd_word on wrd  (cost=0.42..4.44 rows=1 width=0) (actual t
         Index Cond: (word = 'caterpiler'::text)
         Heap Fetches: 0
 Planning time: 0.164 ms
 Execution time: 0.117 ms
```

Either way, the word is spelled wrong, so let's look for what we might have wanted. Again using `file_fdw`:

```
SELECT word FROM words ORDER BY word <-> 'caterpiler' LIMIT 10;

     word
---------------
 cater
 caterpillar
 Caterpillar
 caterpillars
 caterpillar's
 Caterpillar's
 caterer
 caterer's
 caters
 catered
(10 rows)

 Limit  (cost=11583.61..11583.64 rows=10 width=32) (actual time=1431.591..1431.594 rows=
   ->  Sort  (cost=11583.61..11804.76 rows=88459 width=32) (actual time=1431.589..1431.5
         Sort Key: ((word <-> 'caterpiler'::text))
         Sort Method: top-N heapsort  Memory: 25kB
         ->  Foreign Scan on words  (cost=0.00..9672.05 rows=88459 width=32) (actual tim
               Foreign File: /usr/share/dict/words
               Foreign File Size: 4953699
 Planning time: 0.128 ms
 Execution time: 1431.679 ms
```

Using the materialized view:

```
 Limit  (cost=0.29..1.06 rows=10 width=10) (actual time=187.222..188.257 rows=10 loops=1
   ->  Index Scan using wrd_trgm on wrd  (cost=0.29..37020.87 rows=479829 width=10) (act
         Order By: (word <-> 'caterpiler'::text)
 Planning time: 0.196 ms
 Execution time: 198.640 ms
```

If you can tolerate periodic update of the remote data to the local database, the performance benefit can be substantial.

38.4. Rules on INSERT, UPDATE, and DELETE

Rules that are defined on INSERT, UPDATE, and DELETE are significantly different from the view rules described in the previous section. First, their CREATE RULE command allows more:

- They are allowed to have no action.
- They can have multiple actions.
- They can be INSTEAD or ALSO (the default).
- The pseudorelations NEW and OLD become useful.
- They can have rule qualifications.

Second, they don't modify the query tree in place. Instead they create zero or more new query trees and can throw away the original one.

38.4.1. How Update Rules Work

Keep the syntax:

```
CREATE [ OR REPLACE ] RULE name AS ON event
    TO table [ WHERE condition ]
    DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command ... ) }
```

in mind. In the following, *update rules* means rules that are defined on INSERT, UPDATE, or DELETE.

Update rules get applied by the rule system when the result relation and the command type of a query tree are equal to the object and event given in the CREATE RULE command. For update rules, the rule system creates a list of query trees. Initially the query-tree list is empty. There can be zero (NOTHING key word), one, or multiple actions. To simplify, we will look at a rule with one action. This rule can have a qualification or not and it can be INSTEAD or ALSO (the default).

What is a rule qualification? It is a restriction that tells when the actions of the rule should be done and when not. This qualification can only reference the pseudorelations NEW and/or OLD, which basically represent the relation that was given as object (but with a special meaning).

So we have three cases that produce the following query trees for a one-action rule.

No qualification, with either ALSO or INSTEAD

the query tree from the rule action with the original query tree's qualification added

Qualification given and ALSO

the query tree from the rule action with the rule qualification and the original query tree's qualification added

Qualification given and INSTEAD

the query tree from the rule action with the rule qualification and the original query tree's qualification; and the original query tree with the negated rule qualification added

Finally, if the rule is ALSO, the unchanged original query tree is added to the list. Since only qualified INSTEAD rules already add the original query tree, we end up with either one or two output query trees for a rule with one action.

For ON INSERT rules, the original query (if not suppressed by INSTEAD) is done before any actions added by rules. This allows the actions to see the inserted row(s). But for ON UPDATE and ON DELETE

rules, the original query is done after the actions added by rules. This ensures that the actions can see the to-be-updated or to-be-deleted rows; otherwise, the actions might do nothing because they find no rows matching their qualifications.

The query trees generated from rule actions are thrown into the rewrite system again, and maybe more rules get applied resulting in more or less query trees. So a rule's actions must have either a different command type or a different result relation than the rule itself is on, otherwise this recursive process will end up in an infinite loop. (Recursive expansion of a rule will be detected and reported as an error.)

The query trees found in the actions of the `pg_rewrite` system catalog are only templates. Since they can reference the range-table entries for `NEW` and `OLD`, some substitutions have to be made before they can be used. For any reference to `NEW`, the target list of the original query is searched for a corresponding entry. If found, that entry's expression replaces the reference. Otherwise, `NEW` means the same as `OLD` (for an `UPDATE`) or is replaced by a null value (for an `INSERT`). Any reference to `OLD` is replaced by a reference to the range-table entry that is the result relation.

After the system is done applying update rules, it applies view rules to the produced query tree(s). Views cannot insert new update actions so there is no need to apply update rules to the output of view rewriting.

38.4.1.1. A First Rule Step by Step

Say we want to trace changes to the `sl_avail` column in the `shoelace_data` relation. So we set up a log table and a rule that conditionally writes a log entry when an `UPDATE` is performed on `shoelace_data`.

```
CREATE TABLE shoelace_log (
    sl_name    text,          -- shoelace changed
    sl_avail   integer,       -- new available value
    log_who    text,          -- who did it
    log_when   timestamp      -- when
);

CREATE RULE log_shoelace AS ON UPDATE TO shoelace_data
    WHERE NEW.sl_avail <> OLD.sl_avail
    DO INSERT INTO shoelace_log VALUES (
                                    NEW.sl_name,
                                    NEW.sl_avail,
                                    current_user,
                                    current_timestamp
                                );
```

Now someone does:

```
UPDATE shoelace_data SET sl_avail = 6 WHERE sl_name = 'sl7';
```

and we look at the log table:

```
SELECT * FROM shoelace_log;

 sl_name | sl_avail | log_who | log_when
---------+----------+---------+----------------------------------
 sl7     |        6 | Al      | Tue Oct 20 16:14:45 1998 MET DST
(1 row)
```

That's what we expected. What happened in the background is the following. The parser created the query tree:

```
UPDATE shoelace_data SET sl_avail = 6
  FROM shoelace_data shoelace_data
 WHERE shoelace_data.sl_name = 'sl7';
```

There is a rule `log_shoelace` that is `ON UPDATE` with the rule qualification expression:

```
NEW.sl_avail <> OLD.sl_avail
```

and the action:

```
INSERT INTO shoelace_log VALUES (
       new.sl_name, new.sl_avail,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old;
```

(This looks a little strange since you cannot normally write `INSERT ... VALUES ... FROM`. The `FROM` clause here is just to indicate that there are range-table entries in the query tree for `new` and `old`. These are needed so that they can be referenced by variables in the `INSERT` command's query tree.)

The rule is a qualified `ALSO` rule, so the rule system has to return two query trees: the modified rule action and the original query tree. In step 1, the range table of the original query is incorporated into the rule's action query tree. This results in:

```
INSERT INTO shoelace_log VALUES (
       new.sl_name, new.sl_avail,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old,
       shoelace_data shoelace_data;
```

In step 2, the rule qualification is added to it, so the result set is restricted to rows where `sl_avail` changes:

```
INSERT INTO shoelace_log VALUES (
       new.sl_name, new.sl_avail,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old,
       shoelace_data shoelace_data
 WHERE new.sl_avail <> old.sl_avail;
```

(This looks even stranger, since `INSERT ... VALUES` doesn't have a `WHERE` clause either, but the planner and executor will have no difficulty with it. They need to support this same functionality anyway for `INSERT ... SELECT`.)

In step 3, the original query tree's qualification is added, restricting the result set further to only the rows that would have been touched by the original query:

```
INSERT INTO shoelace_log VALUES (
       new.sl_name, new.sl_avail,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old,
       shoelace_data shoelace_data
 WHERE new.sl_avail <> old.sl_avail
   AND shoelace_data.sl_name = 'sl7';
```

Step 4 replaces references to NEW by the target list entries from the original query tree or by the matching variable references from the result relation:

```
INSERT INTO shoelace_log VALUES (
       shoelace_data.sl_name, 6,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old,
       shoelace_data shoelace_data
 WHERE 6 <> old.sl_avail
   AND shoelace_data.sl_name = 'sl7';
```

Step 5 changes OLD references into result relation references:

```
INSERT INTO shoelace_log VALUES (
       shoelace_data.sl_name, 6,
       current_user, current_timestamp )
  FROM shoelace_data new, shoelace_data old,
       shoelace_data shoelace_data
 WHERE 6 <> shoelace_data.sl_avail
   AND shoelace_data.sl_name = 'sl7';
```

That's it. Since the rule is ALSO, we also output the original query tree. In short, the output from the rule system is a list of two query trees that correspond to these statements:

```
INSERT INTO shoelace_log VALUES (
       shoelace_data.sl_name, 6,
       current_user, current_timestamp )
  FROM shoelace_data
 WHERE 6 <> shoelace_data.sl_avail
   AND shoelace_data.sl_name = 'sl7';

UPDATE shoelace_data SET sl_avail = 6
 WHERE sl_name = 'sl7';
```

These are executed in this order, and that is exactly what the rule was meant to do.

The substitutions and the added qualifications ensure that, if the original query would be, say:

```
UPDATE shoelace_data SET sl_color = 'green'
 WHERE sl_name = 'sl7';
```

no log entry would get written. In that case, the original query tree does not contain a target list entry for sl_avail, so NEW.sl_avail will get replaced by shoelace_data.sl_avail. Thus, the extra command generated by the rule is:

```
INSERT INTO shoelace_log VALUES (
       shoelace_data.sl_name, shoelace_data.sl_avail,
       current_user, current_timestamp )
  FROM shoelace_data
 WHERE shoelace_data.sl_avail <> shoelace_data.sl_avail
   AND shoelace_data.sl_name = 'sl7';
```

and that qualification will never be true.

It will also work if the original query modifies multiple rows. So if someone issued the command:

```
UPDATE shoelace_data SET sl_avail = 0
 WHERE sl_color = 'black';
```

four rows in fact get updated (sl1, sl2, sl3, and sl4). But sl3 already has sl_avail = 0. In this case, the original query trees qualification is different and that results in the extra query tree:

```
INSERT INTO shoelace_log
SELECT shoelace_data.sl_name, 0,
       current_user, current_timestamp
  FROM shoelace_data
 WHERE 0 <> shoelace_data.sl_avail
   AND shoelace_data.sl_color = 'black';
```

being generated by the rule. This query tree will surely insert three new log entries. And that's absolutely correct.

Here we can see why it is important that the original query tree is executed last. If the UPDATE had been executed first, all the rows would have already been set to zero, so the logging INSERT would not find any row where 0 <> shoelace_data.sl_avail.

38.4.2. Cooperation with Views

A simple way to protect view relations from the mentioned possibility that someone can try to run INSERT, UPDATE, or DELETE on them is to let those query trees get thrown away. So we could create the rules:

```
CREATE RULE shoe_ins_protect AS ON INSERT TO shoe
    DO INSTEAD NOTHING;
CREATE RULE shoe_upd_protect AS ON UPDATE TO shoe
    DO INSTEAD NOTHING;
CREATE RULE shoe_del_protect AS ON DELETE TO shoe
    DO INSTEAD NOTHING;
```

If someone now tries to do any of these operations on the view relation shoe, the rule system will apply these rules. Since the rules have no actions and are INSTEAD, the resulting list of query trees will be empty and the whole query will become nothing because there is nothing left to be optimized or executed after the rule system is done with it.

A more sophisticated way to use the rule system is to create rules that rewrite the query tree into one that does the right operation on the real tables. To do that on the shoelace view, we create the following rules:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
    DO INSTEAD
    INSERT INTO shoelace_data VALUES (
           NEW.sl_name,
           NEW.sl_avail,
           NEW.sl_color,
           NEW.sl_len,
           NEW.sl_unit
    );

CREATE RULE shoelace_upd AS ON UPDATE TO shoelace
```

```
    DO INSTEAD
    UPDATE shoelace_data
       SET sl_name = NEW.sl_name,
           sl_avail = NEW.sl_avail,
           sl_color = NEW.sl_color,
           sl_len = NEW.sl_len,
           sl_unit = NEW.sl_unit
     WHERE sl_name = OLD.sl_name;

CREATE RULE shoelace_del AS ON DELETE TO shoelace
    DO INSTEAD
    DELETE FROM shoelace_data
     WHERE sl_name = OLD.sl_name;
```

If you want to support `RETURNING` queries on the view, you need to make the rules include `RETURNING` clauses that compute the view rows. This is usually pretty trivial for views on a single table, but it's a bit tedious for join views such as `shoelace`. An example for the insert case is:

```
CREATE RULE shoelace_ins AS ON INSERT TO shoelace
    DO INSTEAD
    INSERT INTO shoelace_data VALUES (
           NEW.sl_name,
           NEW.sl_avail,
           NEW.sl_color,
           NEW.sl_len,
           NEW.sl_unit
    )
    RETURNING
           shoelace_data.*,
           (SELECT shoelace_data.sl_len * u.un_fact
            FROM unit u WHERE shoelace_data.sl_unit = u.un_name);
```

Note that this one rule supports both `INSERT` and `INSERT RETURNING` queries on the view — the `RETURNING` clause is simply ignored for `INSERT`.

Now assume that once in a while, a pack of shoelaces arrives at the shop and a big parts list along with it. But you don't want to manually update the `shoelace` view every time. Instead we setup two little tables: one where you can insert the items from the part list, and one with a special trick. The creation commands for these are:

```
CREATE TABLE shoelace_arrive (
    arr_name    text,
    arr_quant   integer
);

CREATE TABLE shoelace_ok (
    ok_name     text,
    ok_quant    integer
);

CREATE RULE shoelace_ok_ins AS ON INSERT TO shoelace_ok
    DO INSTEAD
    UPDATE shoelace
       SET sl_avail = sl_avail + NEW.ok_quant
     WHERE sl_name = NEW.ok_name;
```

Now you can fill the table `shoelace_arrive` with the data from the parts list:

```
SELECT * FROM shoelace_arrive;

 arr_name | arr_quant
----------+-----------
 sl3      |        10
 sl6      |        20
 sl8      |        20
(3 rows)
```

Take a quick look at the current data:

```
SELECT * FROM shoelace;

 sl_name  | sl_avail | sl_color | sl_len | sl_unit | sl_len_cm
----------+----------+----------+--------+---------+-----------
 sl1      |        5 | black    |     80 | cm      |        80
 sl2      |        6 | black    |    100 | cm      |       100
 sl7      |        6 | brown    |     60 | cm      |        60
 sl3      |        0 | black    |     35 | inch    |      88.9
 sl4      |        8 | black    |     40 | inch    |     101.6
 sl8      |        1 | brown    |     40 | inch    |     101.6
 sl5      |        4 | brown    |      1 | m       |       100
 sl6      |        0 | brown    |    0.9 | m       |        90
(8 rows)
```

Now move the arrived shoelaces in:

```
INSERT INTO shoelace_ok SELECT * FROM shoelace_arrive;
```

and check the results:

```
SELECT * FROM shoelace ORDER BY sl_name;

 sl_name  | sl_avail | sl_color | sl_len | sl_unit | sl_len_cm
----------+----------+----------+--------+---------+-----------
 sl1      |        5 | black    |     80 | cm      |        80
 sl2      |        6 | black    |    100 | cm      |       100
 sl7      |        6 | brown    |     60 | cm      |        60
 sl4      |        8 | black    |     40 | inch    |     101.6
 sl3      |       10 | black    |     35 | inch    |      88.9
 sl8      |       21 | brown    |     40 | inch    |     101.6
 sl5      |        4 | brown    |      1 | m       |       100
 sl6      |       20 | brown    |    0.9 | m       |        90
(8 rows)

SELECT * FROM shoelace_log;

 sl_name | sl_avail | log_who| log_when
---------+----------+--------+----------------------------------
 sl7     |        6 | Al     | Tue Oct 20 19:14:45 1998 MET DST
 sl3     |       10 | Al     | Tue Oct 20 19:25:16 1998 MET DST
 sl6     |       20 | Al     | Tue Oct 20 19:25:16 1998 MET DST
 sl8     |       21 | Al     | Tue Oct 20 19:25:16 1998 MET DST
(4 rows)
```

It's a long way from the one `INSERT ... SELECT` to these results. And the description of the query-tree transformation will be the last in this chapter. First, there is the parser's output:

```
INSERT INTO shoelace_ok
SELECT shoelace_arrive.arr_name, shoelace_arrive.arr_quant
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok;
```

Now the first rule `shoelace_ok_ins` is applied and turns this into:

```
UPDATE shoelace
   SET sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace
 WHERE shoelace.sl_name = shoelace_arrive.arr_name;
```

and throws away the original `INSERT` on `shoelace_ok`. This rewritten query is passed to the rule system again, and the second applied rule `shoelace_upd` produces:

```
UPDATE shoelace_data
   SET sl_name = shoelace.sl_name,
       sl_avail = shoelace.sl_avail + shoelace_arrive.arr_quant,
       sl_color = shoelace.sl_color,
       sl_len = shoelace.sl_len,
       sl_unit = shoelace.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data
 WHERE shoelace.sl_name = shoelace_arrive.arr_name
   AND shoelace_data.sl_name = shoelace.sl_name;
```

Again it's an `INSTEAD` rule and the previous query tree is trashed. Note that this query still uses the view `shoelace`. But the rule system isn't finished with this step, so it continues and applies the `_RETURN` rule on it, and we get:

```
UPDATE shoelace_data
   SET sl_name = s.sl_name,
       sl_avail = s.sl_avail + shoelace_arrive.arr_quant,
       sl_color = s.sl_color,
       sl_len = s.sl_len,
       sl_unit = s.sl_unit
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data,
       shoelace old, shoelace new,
       shoelace_data s, unit u
 WHERE s.sl_name = shoelace_arrive.arr_name
   AND shoelace_data.sl_name = s.sl_name;
```

Finally, the rule `log_shoelace` gets applied, producing the extra query tree:

```
INSERT INTO shoelace_log
SELECT s.sl_name,
       s.sl_avail + shoelace_arrive.arr_quant,
       current_user,
       current_timestamp
```

```
  FROM shoelace_arrive shoelace_arrive, shoelace_ok shoelace_ok,
       shoelace_ok old, shoelace_ok new,
       shoelace shoelace, shoelace old,
       shoelace new, shoelace_data shoelace_data,
       shoelace old, shoelace new,
       shoelace_data s, unit u,
       shoelace_data old, shoelace_data new
       shoelace_log shoelace_log
 WHERE s.sl_name = shoelace_arrive.arr_name
   AND shoelace_data.sl_name = s.sl_name
   AND (s.sl_avail + shoelace_arrive.arr_quant) <> s.sl_avail;
```

After that the rule system runs out of rules and returns the generated query trees.

So we end up with two final query trees that are equivalent to the SQL statements:

```
INSERT INTO shoelace_log
SELECT s.sl_name,
       s.sl_avail + shoelace_arrive.arr_quant,
       current_user,
       current_timestamp
  FROM shoelace_arrive shoelace_arrive, shoelace_data shoelace_data,
       shoelace_data s
 WHERE s.sl_name = shoelace_arrive.arr_name
   AND shoelace_data.sl_name = s.sl_name
   AND s.sl_avail + shoelace_arrive.arr_quant <> s.sl_avail;

UPDATE shoelace_data
   SET sl_avail = shoelace_data.sl_avail + shoelace_arrive.arr_quant
  FROM shoelace_arrive shoelace_arrive,
       shoelace_data shoelace_data,
       shoelace_data s
 WHERE s.sl_name = shoelace_arrive.sl_name
   AND shoelace_data.sl_name = s.sl_name;
```

The result is that data coming from one relation inserted into another, changed into updates on a third, changed into updating a fourth plus logging that final update in a fifth gets reduced into two queries.

There is a little detail that's a bit ugly. Looking at the two queries, it turns out that the `shoelace_data` relation appears twice in the range table where it could definitely be reduced to one. The planner does not handle it and so the execution plan for the rule systems output of the `INSERT` will be

```
Nested Loop
  ->  Merge Join
        ->  Seq Scan
              ->  Sort
                    ->  Seq Scan on s
        ->  Seq Scan
              ->  Sort
                    ->  Seq Scan on shoelace_arrive
  ->  Seq Scan on shoelace_data
```

while omitting the extra range table entry would result in a

```
Merge Join
  ->  Seq Scan
        ->  Sort
              ->  Seq Scan on s
```

```
  ->  Seq Scan
        ->  Sort
              ->  Seq Scan on shoelace_arrive
```

which produces exactly the same entries in the log table. Thus, the rule system caused one extra scan on the table `shoelace_data` that is absolutely not necessary. And the same redundant scan is done once more in the `UPDATE`. But it was a really hard job to make that all possible at all.

Now we make a final demonstration of the PostgreSQL rule system and its power. Say you add some shoelaces with extraordinary colors to your database:

```
INSERT INTO shoelace VALUES ('sl9', 0, 'pink', 35.0, 'inch', 0.0);
INSERT INTO shoelace VALUES ('sl10', 1000, 'magenta', 40.0, 'inch', 0.0);
```

We would like to make a view to check which `shoelace` entries do not fit any shoe in color. The view for this is:

```
CREATE VIEW shoelace_mismatch AS
    SELECT * FROM shoelace WHERE NOT EXISTS
        (SELECT shoename FROM shoe WHERE slcolor = sl_color);
```

Its output is:

```
SELECT * FROM shoelace_mismatch;

 sl_name | sl_avail | sl_color | sl_len | sl_unit | sl_len_cm
---------+----------+----------+--------+---------+-----------
 sl9     |        0 | pink     |     35 | inch    |      88.9
 sl10    |     1000 | magenta  |     40 | inch    |     101.6
```

Now we want to set it up so that mismatching shoelaces that are not in stock are deleted from the database. To make it a little harder for PostgreSQL, we don't delete it directly. Instead we create one more view:

```
CREATE VIEW shoelace_can_delete AS
    SELECT * FROM shoelace_mismatch WHERE sl_avail = 0;
```

and do it this way:

```
DELETE FROM shoelace WHERE EXISTS
    (SELECT * FROM shoelace_can_delete
             WHERE sl_name = shoelace.sl_name);
```

Voilà:

```
SELECT * FROM shoelace;

 sl_name | sl_avail | sl_color | sl_len | sl_unit | sl_len_cm
---------+----------+----------+--------+---------+-----------
 sl1     |        5 | black    |     80 | cm      |         80
 sl2     |        6 | black    |    100 | cm      |        100
 sl7     |        6 | brown    |     60 | cm      |         60
 sl4     |        8 | black    |     40 | inch    |      101.6
 sl3     |       10 | black    |     35 | inch    |       88.9
 sl8     |       21 | brown    |     40 | inch    |      101.6
 sl10    |     1000 | magenta  |     40 | inch    |      101.6
 sl5     |        4 | brown    |      1 | m       |        100
```

```
 sl6     |       20 | brown    |    0.9 | m       |        90
(9 rows)
```

A DELETE on a view, with a subquery qualification that in total uses 4 nesting/joined views, where one of them itself has a subquery qualification containing a view and where calculated view columns are used, gets rewritten into one single query tree that deletes the requested data from a real table.

There are probably only a few situations out in the real world where such a construct is necessary. But it makes you feel comfortable that it works.

38.5. Rules and Privileges

Due to rewriting of queries by the PostgreSQL rule system, other tables/views than those used in the original query get accessed. When update rules are used, this can include write access to tables.

Rewrite rules don't have a separate owner. The owner of a relation (table or view) is automatically the owner of the rewrite rules that are defined for it. The PostgreSQL rule system changes the behavior of the default access control system. Relations that are used due to rules get checked against the privileges of the rule owner, not the user invoking the rule. This means that a user only needs the required privileges for the tables/views that he names explicitly in his queries.

For example: A user has a list of phone numbers where some of them are private, the others are of interest for the secretary of the office. He can construct the following:

```
CREATE TABLE phone_data (person text, phone text, private boolean);
CREATE VIEW phone_number AS
    SELECT person, CASE WHEN NOT private THEN phone END AS phone
    FROM phone_data;
GRANT SELECT ON phone_number TO secretary;
```

Nobody except him (and the database superusers) can access the phone_data table. But because of the GRANT, the secretary can run a SELECT on the phone_number view. The rule system will rewrite the SELECT from phone_number into a SELECT from phone_data. Since the user is the owner of phone_number and therefore the owner of the rule, the read access to phone_data is now checked against his privileges and the query is permitted. The check for accessing phone_number is also performed, but this is done against the invoking user, so nobody but the user and the secretary can use it.

The privileges are checked rule by rule. So the secretary is for now the only one who can see the public phone numbers. But the secretary can setup another view and grant access to that to the public. Then, anyone can see the phone_number data through the secretary's view. What the secretary cannot do is to create a view that directly accesses phone_data. (Actually he can, but it will not work since every access will be denied during the permission checks.) And as soon as the user will notice, that the secretary opened his phone_number view, he can revoke his access. Immediately, any access to the secretary's view would fail.

One might think that this rule-by-rule checking is a security hole, but in fact it isn't. But if it did not work this way, the secretary could set up a table with the same columns as phone_number and copy the data to there once per day. Then it's his own data and he can grant access to everyone he wants. A GRANT command means, "I trust you". If someone you trust does the thing above, it's time to think it over and then use REVOKE.

Note that while views can be used to hide the contents of certain columns using the technique shown above, they cannot be used to reliably conceal the data in unseen rows unless the security_barrier flag has been set. For example, the following view is insecure:

```
CREATE VIEW phone_number AS
    SELECT person, phone FROM phone_data WHERE phone NOT LIKE '412%';
```

This view might seem secure, since the rule system will rewrite any SELECT from phone_number into a SELECT from phone_data and add the qualification that only entries where phone does not begin with 412 are wanted. But if the user can create his or her own functions, it is not difficult to convince the planner to execute the user-defined function prior to the NOT LIKE expression. For example:

```
CREATE FUNCTION tricky(text, text) RETURNS bool AS $$
BEGIN
    RAISE NOTICE '% => %', $1, $2;
    RETURN true;
END
$$ LANGUAGE plpgsql COST 0.00000000000000000001;

SELECT * FROM phone_number WHERE tricky(person, phone);
```

Every person and phone number in the phone_data table will be printed as a NOTICE, because the planner will choose to execute the inexpensive tricky function before the more expensive NOT LIKE. Even if the user is prevented from defining new functions, built-in functions can be used in similar attacks. (For example, most casting functions include their input values in the error messages they produce.)

Similar considerations apply to update rules. In the examples of the previous section, the owner of the tables in the example database could grant the privileges SELECT, INSERT, UPDATE, and DELETE on the shoelace view to someone else, but only SELECT on shoelace_log. The rule action to write log entries will still be executed successfully, and that other user could see the log entries. But he cannot create fake entries, nor could he manipulate or remove existing ones. In this case, there is no possibility of subverting the rules by convincing the planner to alter the order of operations, because the only rule which references shoelace_log is an unqualified INSERT. This might not be true in more complex scenarios.

When it is necessary for a view to provide row-level security, the security_barrier attribute should be applied to the view. This prevents maliciously-chosen functions and operators from being invoked on rows until after the view has done its work. For example, if the view shown above had been created like this, it would be secure:

```
CREATE VIEW phone_number WITH (security_barrier) AS
    SELECT person, phone FROM phone_data WHERE phone NOT LIKE '412%';
```

Views created with the security_barrier may perform far worse than views created without this option. In general, there is no way to avoid this: the fastest possible plan must be rejected if it may compromise security. For this reason, this option is not enabled by default.

The query planner has more flexibility when dealing with functions that have no side effects. Such functions are referred to as LEAKPROOF, and include many simple, commonly used operators, such as many equality operators. The query planner can safely allow such functions to be evaluated at any point in the query execution process, since invoking them on rows invisible to the user will not leak any information about the unseen rows. In contrast, a function that might throw an error depending on the values received as arguments (such as one that throws an error in the event of overflow or

division by zero) are not leak-proof, and could provide significant information about the unseen rows if applied before the security view's row filters.

It is important to understand that even a view created with the `security_barrier` option is intended to be secure only in the limited sense that the contents of the invisible tuples will not be passed to possibly-insecure functions. The user may well have other means of making inferences about the unseen data; for example, they can see the query plan using `EXPLAIN`, or measure the run time of queries against the view. A malicious attacker might be able to infer something about the amount of unseen data, or even gain some information about the data distribution or most common values (since these things may affect the run time of the plan; or even, since they are also reflected in the optimizer statistics, the choice of plan). If these types of "covert channel" attacks are of concern, it is probably unwise to grant any access to the data at all.

38.6. Rules and Command Status

The PostgreSQL server returns a command status string, such as `INSERT 149592 1`, for each command it receives. This is simple enough when there are no rules involved, but what happens when the query is rewritten by rules?

Rules affect the command status as follows:

- If there is no unconditional `INSTEAD` rule for the query, then the originally given query will be executed, and its command status will be returned as usual. (But note that if there were any conditional `INSTEAD` rules, the negation of their qualifications will have been added to the original query. This might reduce the number of rows it processes, and if so the reported status will be affected.)
- If there is any unconditional `INSTEAD` rule for the query, then the original query will not be executed at all. In this case, the server will return the command status for the last query that was inserted by an `INSTEAD` rule (conditional or unconditional) and is of the same command type (`INSERT`, `UPDATE`, or `DELETE`) as the original query. If no query meeting those requirements is added by any rule, then the returned command status shows the original query type and zeroes for the row-count and OID fields.

The programmer can ensure that any desired `INSTEAD` rule is the one that sets the command status in the second case, by giving it the alphabetically last rule name among the active rules, so that it gets applied last.

38.7. Rules Versus Triggers

Many things that can be done using triggers can also be implemented using the PostgreSQL rule system. One of the things that cannot be implemented by rules are some kinds of constraints, especially foreign keys. It is possible to place a qualified rule that rewrites a command to `NOTHING` if the value of a column does not appear in another table. But then the data is silently thrown away and that's not a good idea. If checks for valid values are required, and in the case of an invalid value an error message should be generated, it must be done by a trigger.

In this chapter, we focused on using rules to update views. All of the update rule examples in this chapter can also be implemented using `INSTEAD OF` triggers on the views. Writing such triggers is often easier than writing rules, particularly if complex logic is required to perform the update.

For the things that can be implemented by both, which is best depends on the usage of the database. A trigger is fired once for each affected row. A rule modifies the query or generates an additional query. So if many rows are affected in one statement, a rule issuing one extra command is likely to be faster than a trigger that is called for every single row and must re-determine what to do many times. However, the trigger approach is conceptually far simpler than the rule approach, and is easier for novices to get right.

Here we show an example of how the choice of rules versus triggers plays out in one situation. There are two tables:

```
CREATE TABLE computer (
    hostname        text,    -- indexed
    manufacturer    text     -- indexed
);

CREATE TABLE software (
    software        text,    -- indexed
    hostname        text     -- indexed
);
```

Both tables have many thousands of rows and the indexes on `hostname` are unique. The rule or trigger should implement a constraint that deletes rows from `software` that reference a deleted computer. The trigger would use this command:

```
DELETE FROM software WHERE hostname = $1;
```

Since the trigger is called for each individual row deleted from `computer`, it can prepare and save the plan for this command and pass the `hostname` value in the parameter. The rule would be written as:

```
CREATE RULE computer_del AS ON DELETE TO computer
    DO DELETE FROM software WHERE hostname = OLD.hostname;
```

Now we look at different types of deletes. In the case of a:

```
DELETE FROM computer WHERE hostname = 'mypc.local.net';
```

the table `computer` is scanned by index (fast), and the command issued by the trigger would also use an index scan (also fast). The extra command from the rule would be:

```
DELETE FROM software WHERE computer.hostname = 'mypc.local.net'
                       AND software.hostname = computer.hostname;
```

Since there are appropriate indexes setup, the planner will create a plan of

```
Nestloop
  ->  Index Scan using comp_hostidx on computer
  ->  Index Scan using soft_hostidx on software
```

So there would be not that much difference in speed between the trigger and the rule implementation.

With the next delete we want to get rid of all the 2000 computers where the `hostname` starts with `old`. There are two possible commands to do that. One is:

```
DELETE FROM computer WHERE hostname >= 'old'
                       AND hostname <  'ole'
```

The command added by the rule will be:

```
DELETE FROM software WHERE computer.hostname >= 'old' AND computer.hostname < 'ole'
                       AND software.hostname = computer.hostname;
```

with the plan

```
Hash Join
  ->  Seq Scan on software
  ->  Hash
    ->  Index Scan using comp_hostidx on computer
```

The other possible command is:

```
DELETE FROM computer WHERE hostname ~ '^old';
```

which results in the following executing plan for the command added by the rule:

```
Nestloop
  ->  Index Scan using comp_hostidx on computer
  ->  Index Scan using soft_hostidx on software
```

This shows, that the planner does not realize that the qualification for `hostname` in `computer` could also be used for an index scan on `software` when there are multiple qualification expressions combined with `AND`, which is what it does in the regular-expression version of the command. The trigger will get invoked once for each of the 2000 old computers that have to be deleted, and that will result in one index scan over `computer` and 2000 index scans over `software`. The rule implementation will do it with two commands that use indexes. And it depends on the overall size of the table `software` whether the rule will still be faster in the sequential scan situation. 2000 command executions from the trigger over the SPI manager take some time, even if all the index blocks will soon be in the cache.

The last command we look at is:

```
DELETE FROM computer WHERE manufacturer = 'bim';
```

Again this could result in many rows to be deleted from `computer`. So the trigger will again run many commands through the executor. The command generated by the rule will be:

```
DELETE FROM software WHERE computer.manufacturer = 'bim'
                       AND software.hostname = computer.hostname;
```

The plan for that command will again be the nested loop over two index scans, only using a different index on `computer`:

```
Nestloop
  ->  Index Scan using comp_manufidx on computer
  ->  Index Scan using soft_hostidx on software
```

In any of these cases, the extra commands from the rule system will be more or less independent from the number of affected rows in a command.

The summary is, rules will only be significantly slower than triggers if their actions result in large and badly qualified joins, a situation where the planner fails.

Chapter 39. Procedural Languages

PostgreSQL allows user-defined functions to be written in other languages besides SQL and C. These other languages are generically called *procedural languages* (PLs). For a function written in a procedural language, the database server has no built-in knowledge about how to interpret the function's source text. Instead, the task is passed to a special handler that knows the details of the language. The handler could either do all the work of parsing, syntax analysis, execution, etc. itself, or it could serve as "glue" between PostgreSQL and an existing implementation of a programming language. The handler itself is a C language function compiled into a shared object and loaded on demand, just like any other C function.

There are currently four procedural languages available in the standard PostgreSQL distribution: PL/pgSQL (Chapter 40), PL/Tcl (Chapter 41), PL/Perl (Chapter 42), and PL/Python (Chapter 43). There are additional procedural languages available that are not included in the core distribution. Appendix H has information about finding them. In addition other languages can be defined by users; the basics of developing a new procedural language are covered in Chapter 52.

39.1. Installing Procedural Languages

A procedural language must be "installed" into each database where it is to be used. But procedural languages installed in the database `template1` are automatically available in all subsequently created databases, since their entries in `template1` will be copied by `CREATE DATABASE`. So the database administrator can decide which languages are available in which databases and can make some languages available by default if he chooses.

For the languages supplied with the standard distribution, it is only necessary to execute `CREATE EXTENSION` *`language_name`* to install the language into the current database. Alternatively, the program createlang can be used to do this from the shell command line. For example, to install the language PL/Perl into the database `template1`, use:

```
createlang plperl template1
```

The manual procedure described below is only recommended for installing languages that have not been packaged as extensions.

Manual Procedural Language Installation

A procedural language is installed in a database in five steps, which must be carried out by a database superuser. In most cases the required SQL commands should be packaged as the installation script of an "extension", so that `CREATE EXTENSION` can be used to execute them.

1. The shared object for the language handler must be compiled and installed into an appropriate library directory. This works in the same way as building and installing modules with regular user-defined C functions does; see Section 35.9.6. Often, the language handler will depend on an external library that provides the actual programming language engine; if so, that must be installed as well.

2. The handler must be declared with the command

```
CREATE FUNCTION handler_function_name()
    RETURNS language_handler
    AS 'path-to-shared-object'
    LANGUAGE C;
```

The special return type of `language_handler` tells the database system that this function does not return one of the defined SQL data types and is not directly usable in SQL statements.

3. Optionally, the language handler can provide an "inline" handler function that executes anonymous code blocks (DO commands) written in this language. If an inline handler function is provided by the language, declare it with a command like

```
CREATE FUNCTION inline_function_name(internal)
    RETURNS void
    AS 'path-to-shared-object'
    LANGUAGE C;
```

4. Optionally, the language handler can provide a "validator" function that checks a function definition for correctness without actually executing it. The validator function is called by `CREATE FUNCTION` if it exists. If a validator function is provided by the language, declare it with a command like

```
CREATE FUNCTION validator_function_name(oid)
    RETURNS void
    AS 'path-to-shared-object'
    LANGUAGE C STRICT;
```

5. Finally, the PL must be declared with the command

```
CREATE [TRUSTED] [PROCEDURAL] LANGUAGE language-name
    HANDLER handler_function_name
    [INLINE inline_function_name]
    [VALIDATOR validator_function_name] ;
```

The optional key word `TRUSTED` specifies that the language does not grant access to data that the user would not otherwise have. Trusted languages are designed for ordinary database users (those without superuser privilege) and allows them to safely create functions and trigger procedures. Since PL functions are executed inside the database server, the `TRUSTED` flag should only be given for languages that do not allow access to database server internals or the file system. The languages PL/pgSQL, PL/Tcl, and PL/Perl are considered trusted; the languages PL/TclU, PL/PerlU, and PL/PythonU are designed to provide unlimited functionality and should *not* be marked trusted.

Example 39-1 shows how the manual installation procedure would work with the language PL/Perl.

Example 39-1. Manual Installation of PL/Perl

The following command tells the database server where to find the shared object for the PL/Perl language's call handler function:

```
CREATE FUNCTION plperl_call_handler() RETURNS language_handler AS
    '$libdir/plperl' LANGUAGE C;
```

PL/Perl has an inline handler function and a validator function, so we declare those too:

```
CREATE FUNCTION plperl_inline_handler(internal) RETURNS void AS
    '$libdir/plperl' LANGUAGE C;

CREATE FUNCTION plperl_validator(oid) RETURNS void AS
    '$libdir/plperl' LANGUAGE C STRICT;
```

The command:

```
CREATE TRUSTED PROCEDURAL LANGUAGE plperl
    HANDLER plperl_call_handler
    INLINE plperl_inline_handler
    VALIDATOR plperl_validator;
```

then defines that the previously declared functions should be invoked for functions and trigger procedures where the language attribute is `plperl`.

In a default PostgreSQL installation, the handler for the PL/pgSQL language is built and installed into the "library" directory; furthermore, the PL/pgSQL language itself is installed in all databases. If Tcl support is configured in, the handlers for PL/Tcl and PL/TclU are built and installed in the library directory, but the language itself is not installed in any database by default. Likewise, the PL/Perl and PL/PerlU handlers are built and installed if Perl support is configured, and the PL/PythonU handler is installed if Python support is configured, but these languages are not installed by default.

Chapter 40. PL/pgSQL - SQL Procedural Language

40.1. Overview

PL/pgSQL is a loadable procedural language for the PostgreSQL database system. The design goals of PL/pgSQL were to create a loadable procedural language that

- can be used to create functions and trigger procedures,
- adds control structures to the SQL language,
- can perform complex computations,
- inherits all user-defined types, functions, and operators,
- can be defined to be trusted by the server,
- is easy to use.

Functions created with PL/pgSQL can be used anywhere that built-in functions could be used. For example, it is possible to create complex conditional computation functions and later use them to define operators or use them in index expressions.

In PostgreSQL 9.0 and later, PL/pgSQL is installed by default. However it is still a loadable module, so especially security-conscious administrators could choose to remove it.

40.1.1. Advantages of Using PL/pgSQL

SQL is the language PostgreSQL and most other relational databases use as query language. It's portable and easy to learn. But every SQL statement must be executed individually by the database server.

That means that your client application must send each query to the database server, wait for it to be processed, receive and process the results, do some computation, then send further queries to the server. All this incurs interprocess communication and will also incur network overhead if your client is on a different machine than the database server.

With PL/pgSQL you can group a block of computation and a series of queries *inside* the database server, thus having the power of a procedural language and the ease of use of SQL, but with considerable savings of client/server communication overhead.

- Extra round trips between client and server are eliminated
- Intermediate results that the client does not need do not have to be marshaled or transferred between server and client
- Multiple rounds of query parsing can be avoided

This can result in a considerable performance increase as compared to an application that does not use stored functions.

Also, with PL/pgSQL you can use all the data types, operators and functions of SQL.

40.1.2. Supported Argument and Result Data Types

Functions written in PL/pgSQL can accept as arguments any scalar or array data type supported by the server, and they can return a result of any of these types. They can also accept or return any composite type (row type) specified by name. It is also possible to declare a PL/pgSQL function as returning `record`, which means that the result is a row type whose columns are determined by specification in the calling query, as discussed in Section 7.2.1.4.

PL/pgSQL functions can be declared to accept a variable number of arguments by using the `VARIADIC` marker. This works exactly the same way as for SQL functions, as discussed in Section 35.4.5.

PL/pgSQL functions can also be declared to accept and return the polymorphic types `anyelement`, `anyarray`, `anynonarray`, `anyenum`, and `anyrange`. The actual data types handled by a polymorphic function can vary from call to call, as discussed in Section 35.2.5. An example is shown in Section 40.3.1.

PL/pgSQL functions can also be declared to return a "set" (or table) of any data type that can be returned as a single instance. Such a function generates its output by executing `RETURN NEXT` for each desired element of the result set, or by using `RETURN QUERY` to output the result of evaluating a query.

Finally, a PL/pgSQL function can be declared to return `void` if it has no useful return value.

PL/pgSQL functions can also be declared with output parameters in place of an explicit specification of the return type. This does not add any fundamental capability to the language, but it is often convenient, especially for returning multiple values. The `RETURNS TABLE` notation can also be used in place of `RETURNS SETOF`.

Specific examples appear in Section 40.3.1 and Section 40.6.1.

40.2. Structure of PL/pgSQL

PL/pgSQL is a block-structured language. The complete text of a function definition must be a *block*. A block is defined as:

```
[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
END [ label ];
```

Each declaration and each statement within a block is terminated by a semicolon. A block that appears within another block must have a semicolon after `END`, as shown above; however the final `END` that concludes a function body does not require a semicolon.

> **Tip:** A common mistake is to write a semicolon immediately after `BEGIN`. This is incorrect and will result in a syntax error.

A *label* is only needed if you want to identify the block for use in an EXIT statement, or to qualify the names of the variables declared in the block. If a label is given after END, it must match the label at the block's beginning.

All key words are case-insensitive. Identifiers are implicitly converted to lower case unless double-quoted, just as they are in ordinary SQL commands.

Comments work the same way in PL/pgSQL code as in ordinary SQL. A double dash (--) starts a comment that extends to the end of the line. A /* starts a block comment that extends to the matching occurrence of */. Block comments nest.

Any statement in the statement section of a block can be a *subblock*. Subblocks can be used for logical grouping or to localize variables to a small group of statements. Variables declared in a subblock mask any similarly-named variables of outer blocks for the duration of the subblock; but you can access the outer variables anyway if you qualify their names with their block's label. For example:

```
CREATE FUNCTION somefunc() RETURNS integer AS $$
<< outerblock >>
DECLARE
    quantity integer := 30;
BEGIN
    RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 30
    quantity := 50;
    --
    -- Create a subblock
    --
    DECLARE
        quantity integer := 80;
    BEGIN
        RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 80
        RAISE NOTICE 'Outer quantity here is %', outerblock.quantity;  -- Prints 50
    END;

    RAISE NOTICE 'Quantity here is %', quantity;  -- Prints 50

    RETURN quantity;
END;
$$ LANGUAGE plpgsql;
```

> **Note:** There is actually a hidden "outer block" surrounding the body of any PL/pgSQL function. This block provides the declarations of the function's parameters (if any), as well as some special variables such as FOUND (see Section 40.5.5). The outer block is labeled with the function's name, meaning that parameters and special variables can be qualified with the function's name.

It is important not to confuse the use of BEGIN/END for grouping statements in PL/pgSQL with the similarly-named SQL commands for transaction control. PL/pgSQL's BEGIN/END are only for grouping; they do not start or end a transaction. Functions and trigger procedures are always executed within a transaction established by an outer query — they cannot start or commit that transaction, since there would be no context for them to execute in. However, a block containing an EXCEPTION clause effectively forms a subtransaction that can be rolled back without affecting the outer transaction. For more about that see Section 40.6.6.

40.3. Declarations

All variables used in a block must be declared in the declarations section of the block. (The only exceptions are that the loop variable of a `FOR` loop iterating over a range of integer values is automatically declared as an integer variable, and likewise the loop variable of a `FOR` loop iterating over a cursor's result is automatically declared as a record variable.)

PL/pgSQL variables can have any SQL data type, such as `integer`, `varchar`, and `char`.

Here are some examples of variable declarations:

```
user_id integer;
quantity numeric(5);
url varchar;
myrow tablename%ROWTYPE;
myfield tablename.columnname%TYPE;
arow RECORD;
```

The general syntax of a variable declaration is:

```
name [ CONSTANT ] type [ COLLATE collation_name ] [ NOT NULL ] [ { DEFAULT | := | = } expre
```

The `DEFAULT` clause, if given, specifies the initial value assigned to the variable when the block is entered. If the `DEFAULT` clause is not given then the variable is initialized to the SQL null value. The `CONSTANT` option prevents the variable from being assigned to after initialization, so that its value will remain constant for the duration of the block. The `COLLATE` option specifies a collation to use for the variable (see Section 40.3.6). If `NOT NULL` is specified, an assignment of a null value results in a run-time error. All variables declared as `NOT NULL` must have a nonnull default value specified. Equal (=) can be used instead of PL/SQL-compliant `:=`.

A variable's default value is evaluated and assigned to the variable each time the block is entered (not just once per function call). So, for example, assigning `now()` to a variable of type `timestamp` causes the variable to have the time of the current function call, not the time when the function was precompiled.

Examples:

```
quantity integer DEFAULT 32;
url varchar := 'http://mysite.com';
user_id CONSTANT integer := 10;
```

40.3.1. Declaring Function Parameters

Parameters passed to functions are named with the identifiers `$1`, `$2`, etc. Optionally, aliases can be declared for `$n` parameter names for increased readability. Either the alias or the numeric identifier can then be used to refer to the parameter value.

There are two ways to create an alias. The preferred way is to give a name to the parameter in the `CREATE FUNCTION` command, for example:

```
CREATE FUNCTION sales_tax(subtotal real) RETURNS real AS $$
BEGIN
    RETURN subtotal * 0.06;
END;
```

```
$$ LANGUAGE plpgsql;
```

The other way is to explicitly declare an alias, using the declaration syntax

```
name ALIAS FOR $n;
```

The same example in this style looks like:

```
CREATE FUNCTION sales_tax(real) RETURNS real AS $$
DECLARE
    subtotal ALIAS FOR $1;
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

> **Note:** These two examples are not perfectly equivalent. In the first case, `subtotal` could be referenced as `sales_tax.subtotal`, but in the second case it could not. (Had we attached a label to the inner block, `subtotal` could be qualified with that label, instead.)

Some more examples:

```
CREATE FUNCTION instr(varchar, integer) RETURNS integer AS $$
DECLARE
    v_string ALIAS FOR $1;
    index ALIAS FOR $2;
BEGIN
    -- some computations using v_string and index here
END;
$$ LANGUAGE plpgsql;


CREATE FUNCTION concat_selected_fields(in_t sometablename) RETURNS text AS $$
BEGIN
    RETURN in_t.f1 || in_t.f3 || in_t.f5 || in_t.f7;
END;
$$ LANGUAGE plpgsql;
```

When a PL/pgSQL function is declared with output parameters, the output parameters are given `$n` names and optional aliases in just the same way as the normal input parameters. An output parameter is effectively a variable that starts out NULL; it should be assigned to during the execution of the function. The final value of the parameter is what is returned. For instance, the sales-tax example could also be done this way:

```
CREATE FUNCTION sales_tax(subtotal real, OUT tax real) AS $$
BEGIN
    tax := subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

Notice that we omitted `RETURNS real` — we could have included it, but it would be redundant.

Output parameters are most useful when returning multiple values. A trivial example is:

```
CREATE FUNCTION sum_n_product(x int, y int, OUT sum int, OUT prod int) AS $$
BEGIN
    sum := x + y;
    prod := x * y;
END;
$$ LANGUAGE plpgsql;
```

As discussed in Section 35.4.4, this effectively creates an anonymous record type for the function's results. If a `RETURNS` clause is given, it must say `RETURNS record`.

Another way to declare a PL/pgSQL function is with `RETURNS TABLE`, for example:

```
CREATE FUNCTION extended_sales(p_itemno int)
RETURNS TABLE(quantity int, total numeric) AS $$
BEGIN
    RETURN QUERY SELECT s.quantity, s.quantity * s.price FROM sales AS s
                 WHERE s.itemno = p_itemno;
END;
$$ LANGUAGE plpgsql;
```

This is exactly equivalent to declaring one or more `OUT` parameters and specifying `RETURNS SETOF` *`sometype`*.

When the return type of a PL/pgSQL function is declared as a polymorphic type (`anyelement`, `anyarray`, `anynonarray`, `anyenum`, or `anyrange`), a special parameter `$0` is created. Its data type is the actual return type of the function, as deduced from the actual input types (see Section 35.2.5). This allows the function to access its actual return type as shown in Section 40.3.3. `$0` is initialized to null and can be modified by the function, so it can be used to hold the return value if desired, though that is not required. `$0` can also be given an alias. For example, this function works on any data type that has a + operator:

```
CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3 anyelement)
RETURNS anyelement AS $$
DECLARE
    result ALIAS FOR $0;
BEGIN
    result := v1 + v2 + v3;
    RETURN result;
END;
$$ LANGUAGE plpgsql;
```

The same effect can be had by declaring one or more output parameters as polymorphic types. In this case the special `$0` parameter is not used; the output parameters themselves serve the same purpose. For example:

```
CREATE FUNCTION add_three_values(v1 anyelement, v2 anyelement, v3 anyelement,
                                 OUT sum anyelement)
AS $$
BEGIN
    sum := v1 + v2 + v3;
END;
$$ LANGUAGE plpgsql;
```

40.3.2. ALIAS

```
newname ALIAS FOR oldname;
```

The ALIAS syntax is more general than is suggested in the previous section: you can declare an alias for any variable, not just function parameters. The main practical use for this is to assign a different name for variables with predetermined names, such as NEW or OLD within a trigger procedure.

Examples:

```
DECLARE
  prior ALIAS FOR old;
  updated ALIAS FOR new;
```

Since ALIAS creates two different ways to name the same object, unrestricted use can be confusing. It's best to use it only for the purpose of overriding predetermined names.

40.3.3. Copying Types

```
variable%TYPE
```

%TYPE provides the data type of a variable or table column. You can use this to declare variables that will hold database values. For example, let's say you have a column named user_id in your users table. To declare a variable with the same data type as users.user_id you write:

```
user_id users.user_id%TYPE;
```

By using %TYPE you don't need to know the data type of the structure you are referencing, and most importantly, if the data type of the referenced item changes in the future (for instance: you change the type of user_id from integer to real), you might not need to change your function definition.

%TYPE is particularly valuable in polymorphic functions, since the data types needed for internal variables can change from one call to the next. Appropriate variables can be created by applying %TYPE to the function's arguments or result placeholders.

40.3.4. Row Types

```
name table_name%ROWTYPE;
name composite_type_name;
```

A variable of a composite type is called a *row* variable (or *row-type* variable). Such a variable can hold a whole row of a SELECT or FOR query result, so long as that query's column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example rowvar.field.

A row variable can be declared to have the same type as the rows of an existing table or view, by using the *table_name*%ROWTYPE notation; or it can be declared by giving a composite type's name. (Since every table has an associated composite type of the same name, it actually does not matter in PostgreSQL whether you write %ROWTYPE or not. But the form with %ROWTYPE is more portable.)

Parameters to a function can be composite types (complete table rows). In that case, the corresponding identifier $*n* will be a row variable, and fields can be selected from it, for example $1.user_id.

Only the user-defined columns of a table row are accessible in a row-type variable, not the OID or other system columns (because the row could be from a view). The fields of the row type inherit the table's field size or precision for data types such as `char(n)`.

Here is an example of using composite types. `table1` and `table2` are existing tables having at least the mentioned fields:

```
CREATE FUNCTION merge_fields(t_row table1) RETURNS text AS $$
DECLARE
    t2_row table2%ROWTYPE;
BEGIN
    SELECT * INTO t2_row FROM table2 WHERE ... ;
    RETURN t_row.f1 || t2_row.f3 || t_row.f5 || t2_row.f7;
END;
$$ LANGUAGE plpgsql;

SELECT merge_fields(t.*) FROM table1 t WHERE ... ;
```

40.3.5. Record Types

```
name RECORD;
```

Record variables are similar to row-type variables, but they have no predefined structure. They take on the actual row structure of the row they are assigned during a `SELECT` or `FOR` command. The substructure of a record variable can change each time it is assigned to. A consequence of this is that until a record variable is first assigned to, it has no substructure, and any attempt to access a field in it will draw a run-time error.

Note that `RECORD` is not a true data type, only a placeholder. One should also realize that when a PL/pgSQL function is declared to return type `record`, this is not quite the same concept as a record variable, even though such a function might use a record variable to hold its result. In both cases the actual row structure is unknown when the function is written, but for a function returning `record` the actual structure is determined when the calling query is parsed, whereas a record variable can change its row structure on-the-fly.

40.3.6. Collation of PL/pgSQL Variables

When a PL/pgSQL function has one or more parameters of collatable data types, a collation is identified for each function call depending on the collations assigned to the actual arguments, as described in Section 22.2. If a collation is successfully identified (i.e., there are no conflicts of implicit collations among the arguments) then all the collatable parameters are treated as having that collation implicitly. This will affect the behavior of collation-sensitive operations within the function. For example, consider

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b;
END;
$$ LANGUAGE plpgsql;

SELECT less_than(text_field_1, text_field_2) FROM table1;
```

```
SELECT less_than(text_field_1, text_field_2 COLLATE "C") FROM table1;
```

The first use of `less_than` will use the common collation of `text_field_1` and `text_field_2` for the comparison, while the second use will use `C` collation.

Furthermore, the identified collation is also assumed as the collation of any local variables that are of collatable types. Thus this function would not work any differently if it were written as

```
CREATE FUNCTION less_than(a text, b text) RETURNS boolean AS $$
DECLARE
    local_a text := a;
    local_b text := b;
BEGIN
    RETURN local_a < local_b;
END;
$$ LANGUAGE plpgsql;
```

If there are no parameters of collatable data types, or no common collation can be identified for them, then parameters and local variables use the default collation of their data type (which is usually the database's default collation, but could be different for variables of domain types).

A local variable of a collatable data type can have a different collation associated with it by including the `COLLATE` option in its declaration, for example

```
DECLARE
    local_a text COLLATE "en_US";
```

This option overrides the collation that would otherwise be given to the variable according to the rules above.

Also, of course explicit `COLLATE` clauses can be written inside a function if it is desired to force a particular collation to be used in a particular operation. For example,

```
CREATE FUNCTION less_than_c(a text, b text) RETURNS boolean AS $$
BEGIN
    RETURN a < b COLLATE "C";
END;
$$ LANGUAGE plpgsql;
```

This overrides the collations associated with the table columns, parameters, or local variables used in the expression, just as would happen in a plain SQL command.

40.4. Expressions

All expressions used in PL/pgSQL statements are processed using the server's main SQL executor. For example, when you write a PL/pgSQL statement like

```
IF expression THEN ...
```

PL/pgSQL will evaluate the expression by feeding a query like

```
SELECT expression
```

to the main SQL engine. While forming the SELECT command, any occurrences of PL/pgSQL variable names are replaced by parameters, as discussed in detail in Section 40.10.1. This allows the query plan for the SELECT to be prepared just once and then reused for subsequent evaluations with different values of the variables. Thus, what really happens on first use of an expression is essentially a PREPARE command. For example, if we have declared two integer variables x and y, and we write

```
IF x < y THEN ...
```

what happens behind the scenes is equivalent to

```
PREPARE statement_name(integer, integer) AS SELECT $1 < $2;
```

and then this prepared statement is EXECUTEd for each execution of the IF statement, with the current values of the PL/pgSQL variables supplied as parameter values. Normally these details are not important to a PL/pgSQL user, but they are useful to know when trying to diagnose a problem. More information appears in Section 40.10.2.

40.5. Basic Statements

In this section and the following ones, we describe all the statement types that are explicitly understood by PL/pgSQL. Anything not recognized as one of these statement types is presumed to be an SQL command and is sent to the main database engine to execute, as described in Section 40.5.2 and Section 40.5.3.

40.5.1. Assignment

An assignment of a value to a PL/pgSQL variable is written as:

```
variable { := | = } expression;
```

As explained previously, the expression in such a statement is evaluated by means of an SQL SELECT command sent to the main database engine. The expression must yield a single value (possibly a row value, if the variable is a row or record variable). The target variable can be a simple variable (optionally qualified with a block name), a field of a row or record variable, or an element of an array that is a simple variable or field. Equal (=) can be used instead of PL/SQL-compliant :=.

If the expression's result data type doesn't match the variable's data type, or the variable has a specific size/precision (like char(20)), the result value will be implicitly converted by the PL/pgSQL interpreter using the result type's output-function and the variable type's input-function. Note that this could potentially result in run-time errors generated by the input function, if the string form of the result value is not acceptable to the input function.

Examples:

```
tax := subtotal * 0.06;
my_record.user_id := 20;
```

40.5.2. Executing a Command With No Result

For any SQL command that does not return rows, for example INSERT without a RETURNING clause, you can execute the command within a PL/pgSQL function just by writing the command.

Any PL/pgSQL variable name appearing in the command text is treated as a parameter, and then the current value of the variable is provided as the parameter value at run time. This is exactly like the processing described earlier for expressions; for details see Section 40.10.1.

When executing a SQL command in this way, PL/pgSQL may cache and re-use the execution plan for the command, as discussed in Section 40.10.2.

Sometimes it is useful to evaluate an expression or SELECT query but discard the result, for example when calling a function that has side-effects but no useful result value. To do this in PL/pgSQL, use the PERFORM statement:

```
PERFORM query;
```

This executes *query* and discards the result. Write the *query* the same way you would write an SQL SELECT command, but replace the initial keyword SELECT with PERFORM. For WITH queries, use PERFORM and then place the query in parentheses. (In this case, the query can only return one row.) PL/pgSQL variables will be substituted into the query just as for commands that return no result, and the plan is cached in the same way. Also, the special variable FOUND is set to true if the query produced at least one row, or false if it produced no rows (see Section 40.5.5).

> **Note:** One might expect that writing SELECT directly would accomplish this result, but at present the only accepted way to do it is PERFORM. A SQL command that can return rows, such as SELECT, will be rejected as an error unless it has an INTO clause as discussed in the next section.

An example:

```
PERFORM create_mv('cs_session_page_requests_mv', my_query);
```

40.5.3. Executing a Query with a Single-row Result

The result of a SQL command yielding a single row (possibly of multiple columns) can be assigned to a record variable, row-type variable, or list of scalar variables. This is done by writing the base SQL command and adding an INTO clause. For example,

```
SELECT select_expressions INTO [STRICT] target FROM ...;
INSERT ... RETURNING expressions INTO [STRICT] target;
UPDATE ... RETURNING expressions INTO [STRICT] target;
DELETE ... RETURNING expressions INTO [STRICT] target;
```

where *target* can be a record variable, a row variable, or a comma-separated list of simple variables and record/row fields. PL/pgSQL variables will be substituted into the rest of the query, and the plan is cached, just as described above for commands that do not return rows. This works for SELECT, INSERT/UPDATE/DELETE with RETURNING, and utility commands that return row-set results (such as EXPLAIN). Except for the INTO clause, the SQL command is the same as it would be written outside PL/pgSQL.

> **Tip:** Note that this interpretation of SELECT with INTO is quite different from PostgreSQL's regular SELECT INTO command, wherein the INTO target is a newly created table. If you want to create a table from a SELECT result inside a PL/pgSQL function, use the syntax CREATE TABLE ... AS SELECT.

If a row or a variable list is used as target, the query's result columns must exactly match the structure of the target as to number and data types, or else a run-time error occurs. When a record variable is the target, it automatically configures itself to the row type of the query result columns.

The INTO clause can appear almost anywhere in the SQL command. Customarily it is written either just before or just after the list of *select_expressions* in a SELECT command, or at the end of the command for other command types. It is recommended that you follow this convention in case the PL/pgSQL parser becomes stricter in future versions.

If STRICT is not specified in the INTO clause, then *target* will be set to the first row returned by the query, or to nulls if the query returned no rows. (Note that "the first row" is not well-defined unless you've used ORDER BY.) Any result rows after the first row are discarded. You can check the special FOUND variable (see Section 40.5.5) to determine whether a row was returned:

```
SELECT * INTO myrec FROM emp WHERE empname = myname;
IF NOT FOUND THEN
    RAISE EXCEPTION 'employee % not found', myname;
END IF;
```

If the STRICT option is specified, the query must return exactly one row or a run-time error will be reported, either NO_DATA_FOUND (no rows) or TOO_MANY_ROWS (more than one row). You can use an exception block if you wish to catch the error, for example:

```
BEGIN
    SELECT * INTO STRICT myrec FROM emp WHERE empname = myname;
    EXCEPTION
        WHEN NO_DATA_FOUND THEN
            RAISE EXCEPTION 'employee % not found', myname;
        WHEN TOO_MANY_ROWS THEN
            RAISE EXCEPTION 'employee % not unique', myname;
END;
```

Successful execution of a command with STRICT always sets FOUND to true.

For INSERT/UPDATE/DELETE with RETURNING, PL/pgSQL reports an error for more than one returned row, even when STRICT is not specified. This is because there is no option such as ORDER BY with which to determine which affected row should be returned.

If print_strict_params is enabled for the function, then when an error is thrown because the requirements of STRICT are not met, the DETAIL part of the error message will include information about the parameters passed to the query. You can change the print_strict_params setting for all functions by setting plpgsql.print_strict_params, though only subsequent function compilations will be affected. You can also enable it on a per-function basis by using a compiler option, for example:

```
CREATE FUNCTION get_userid(username text) RETURNS int
AS $$
#print_strict_params on
DECLARE
userid int;
BEGIN
```

```
    SELECT users.userid INTO STRICT userid
        FROM users WHERE users.username = get_userid.username;
    RETURN userid;
END
$$ LANGUAGE plpgsql;
```

On failure, this function might produce an error message such as

```
ERROR:  query returned no rows
DETAIL:  parameters: $1 = 'nosuchuser'
CONTEXT:  PL/pgSQL function get_userid(text) line 6 at SQL statement
```

> **Note:** The `STRICT` option matches the behavior of Oracle PL/SQL's `SELECT INTO` and related statements.

To handle cases where you need to process multiple result rows from a SQL query, see Section 40.6.4.

40.5.4. Executing Dynamic Commands

Oftentimes you will want to generate dynamic commands inside your PL/pgSQL functions, that is, commands that will involve different tables or different data types each time they are executed. PL/pgSQL's normal attempts to cache plans for commands (as discussed in Section 40.10.2) will not work in such scenarios. To handle this sort of problem, the `EXECUTE` statement is provided:

```
EXECUTE command-string [ INTO [STRICT] target ] [ USING expression [, ... ] ];
```

where *command-string* is an expression yielding a string (of type `text`) containing the command to be executed. The optional *target* is a record variable, a row variable, or a comma-separated list of simple variables and record/row fields, into which the results of the command will be stored. The optional `USING` expressions supply values to be inserted into the command.

No substitution of PL/pgSQL variables is done on the computed command string. Any required variable values must be inserted in the command string as it is constructed; or you can use parameters as described below.

Also, there is no plan caching for commands executed via `EXECUTE`. Instead, the command is always planned each time the statement is run. Thus the command string can be dynamically created within the function to perform actions on different tables and columns.

The `INTO` clause specifies where the results of a SQL command returning rows should be assigned. If a row or variable list is provided, it must exactly match the structure of the query's results (when a record variable is used, it will configure itself to match the result structure automatically). If multiple rows are returned, only the first will be assigned to the `INTO` variable. If no rows are returned, NULL is assigned to the `INTO` variable(s). If no `INTO` clause is specified, the query results are discarded.

If the `STRICT` option is given, an error is reported unless the query produces exactly one row.

The command string can use parameter values, which are referenced in the command as `$1`, `$2`, etc. These symbols refer to values supplied in the `USING` clause. This method is often preferable to inserting data values into the command string as text: it avoids run-time overhead of converting the values to text and back, and it is much less prone to SQL-injection attacks since there is no need for quoting or escaping. An example is:

```
EXECUTE 'SELECT count(*) FROM mytable WHERE inserted_by = $1 AND inserted <= $2'
   INTO c
   USING checked_user, checked_date;
```

Note that parameter symbols can only be used for data values — if you want to use dynamically determined table or column names, you must insert them into the command string textually. For example, if the preceding query needed to be done against a dynamically selected table, you could do this:

```
EXECUTE 'SELECT count(*) FROM '
    || tabname::regclass
    || ' WHERE inserted_by = $1 AND inserted <= $2'
   INTO c
   USING checked_user, checked_date;
```

Another restriction on parameter symbols is that they only work in `SELECT`, `INSERT`, `UPDATE`, and `DELETE` commands. In other statement types (generically called utility statements), you must insert values textually even if they are just data values.

An `EXECUTE` with a simple constant command string and some `USING` parameters, as in the first example above, is functionally equivalent to just writing the command directly in PL/pgSQL and allowing replacement of PL/pgSQL variables to happen automatically. The important difference is that `EXECUTE` will re-plan the command on each execution, generating a plan that is specific to the current parameter values; whereas PL/pgSQL may otherwise create a generic plan and cache it for re-use. In situations where the best plan depends strongly on the parameter values, it can be helpful to use `EXECUTE` to positively ensure that a generic plan is not selected.

`SELECT INTO` is not currently supported within `EXECUTE`; instead, execute a plain `SELECT` command and specify `INTO` as part of the `EXECUTE` itself.

> **Note:** The PL/pgSQL `EXECUTE` statement is not related to the EXECUTE SQL statement supported by the PostgreSQL server. The server's `EXECUTE` statement cannot be used directly within PL/pgSQL functions (and is not needed).

Example 40-1. Quoting Values In Dynamic Queries

When working with dynamic commands you will often have to handle escaping of single quotes. The recommended method for quoting fixed text in your function body is dollar quoting. (If you have legacy code that does not use dollar quoting, please refer to the overview in Section 40.11.1, which can save you some effort when translating said code to a more reasonable scheme.)

Dynamic values that are to be inserted into the constructed query require careful handling since they might themselves contain quote characters. An example (this assumes that you are using dollar quoting for the function as a whole, so the quote marks need not be doubled):

```
EXECUTE 'UPDATE tbl SET '
        || quote_ident(colname)
        || ' = '
        || quote_literal(newvalue)
        || ' WHERE key = '
        || quote_literal(keyvalue);
```

This example demonstrates the use of the `quote_ident` and `quote_literal` functions (see Section 9.4). For safety, expressions containing column or table identifiers should be passed through

`quote_ident` before insertion in a dynamic query. Expressions containing values that should be literal strings in the constructed command should be passed through `quote_literal`. These functions take the appropriate steps to return the input text enclosed in double or single quotes respectively, with any embedded special characters properly escaped.

Because `quote_literal` is labeled `STRICT`, it will always return null when called with a null argument. In the above example, if `newvalue` or `keyvalue` were null, the entire dynamic query string would become null, leading to an error from `EXECUTE`. You can avoid this problem by using the `quote_nullable` function, which works the same as `quote_literal` except that when called with a null argument it returns the string `NULL`. For example,

```
EXECUTE 'UPDATE tbl SET '
        || quote_ident(colname)
        || ' = '
        || quote_nullable(newvalue)
        || ' WHERE key = '
        || quote_nullable(keyvalue);
```

If you are dealing with values that might be null, you should usually use `quote_nullable` in place of `quote_literal`.

As always, care must be taken to ensure that null values in a query do not deliver unintended results. For example the `WHERE` clause

```
'WHERE key = ' || quote_nullable(keyvalue)
```

will never succeed if `keyvalue` is null, because the result of using the equality operator = with a null operand is always null. If you wish null to work like an ordinary key value, you would need to rewrite the above as

```
'WHERE key IS NOT DISTINCT FROM ' || quote_nullable(keyvalue)
```

(At present, `IS NOT DISTINCT FROM` is handled much less efficiently than =, so don't do this unless you must. See Section 9.2 for more information on nulls and `IS DISTINCT`.)

Note that dollar quoting is only useful for quoting fixed text. It would be a very bad idea to try to write this example as:

```
EXECUTE 'UPDATE tbl SET '
        || quote_ident(colname)
        || ' = $$'
        || newvalue
        || '$$ WHERE key = '
        || quote_literal(keyvalue);
```

because it would break if the contents of `newvalue` happened to contain `$$`. The same objection would apply to any other dollar-quoting delimiter you might pick. So, to safely quote text that is not known in advance, you *must* use `quote_literal`, `quote_nullable`, or `quote_ident`, as appropriate.

Dynamic SQL statements can also be safely constructed using the `format` function (see Section 9.4). For example:

```
EXECUTE format('UPDATE tbl SET %I = %L WHERE key = %L', colname, newvalue, keyvalue);
```

The `format` function can be used in conjunction with the `USING` clause:

```
EXECUTE format('UPDATE tbl SET %I = $1 WHERE key = $2', colname)
   USING newvalue, keyvalue;
```

This form is more efficient, because the parameters `newvalue` and `keyvalue` are not converted to text.

A much larger example of a dynamic command and `EXECUTE` can be seen in Example 40-9, which builds and executes a `CREATE FUNCTION` command to define a new function.

40.5.5. Obtaining the Result Status

There are several ways to determine the effect of a command. The first method is to use the GET DIAGNOSTICS command, which has the form:

```
GET [ CURRENT ] DIAGNOSTICS variable { = | := } item [ , ... ];
```

This command allows retrieval of system status indicators. Each *item* is a key word identifying a status value to be assigned to the specified variable (which should be of the right data type to receive it). The currently available status items are ROW_COUNT, the number of rows processed by the last SQL command sent to the SQL engine, and RESULT_OID, the OID of the last row inserted by the most recent SQL command. Note that RESULT_OID is only useful after an INSERT command into a table containing OIDs. Colon-equal (:=) can be used instead of SQL-standard = for GET DIAGNOSTICS.

An example:

```
GET DIAGNOSTICS integer_var = ROW_COUNT;
```

The second method to determine the effects of a command is to check the special variable named FOUND, which is of type boolean. FOUND starts out false within each PL/pgSQL function call. It is set by each of the following types of statements:

- A SELECT INTO statement sets FOUND true if a row is assigned, false if no row is returned.
- A PERFORM statement sets FOUND true if it produces (and discards) one or more rows, false if no row is produced.
- UPDATE, INSERT, and DELETE statements set FOUND true if at least one row is affected, false if no row is affected.
- A FETCH statement sets FOUND true if it returns a row, false if no row is returned.
- A MOVE statement sets FOUND true if it successfully repositions the cursor, false otherwise.
- A FOR or FOREACH statement sets FOUND true if it iterates one or more times, else false. FOUND is set this way when the loop exits; inside the execution of the loop, FOUND is not modified by the loop statement, although it might be changed by the execution of other statements within the loop body.
- RETURN QUERY and RETURN QUERY EXECUTE statements set FOUND true if the query returns at least one row, false if no row is returned.

Other PL/pgSQL statements do not change the state of FOUND. Note in particular that EXECUTE changes the output of GET DIAGNOSTICS, but does not change FOUND.

FOUND is a local variable within each PL/pgSQL function; any changes to it affect only the current function.

40.5.6. Doing Nothing At All

Sometimes a placeholder statement that does nothing is useful. For example, it can indicate that one arm of an if/then/else chain is deliberately empty. For this purpose, use the NULL statement:

```
NULL;
```

For example, the following two fragments of code are equivalent:

```
BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN
        NULL;  -- ignore the error
END;

BEGIN
    y := x / 0;
EXCEPTION
    WHEN division_by_zero THEN  -- ignore the error
END;
```

Which is preferable is a matter of taste.

> **Note:** In Oracle's PL/SQL, empty statement lists are not allowed, and so `NULL` statements are *required* for situations such as this. PL/pgSQL allows you to just write nothing, instead.

40.6. Control Structures

Control structures are probably the most useful (and important) part of PL/pgSQL. With PL/pgSQL's control structures, you can manipulate PostgreSQL data in a very flexible and powerful way.

40.6.1. Returning From a Function

There are two commands available that allow you to return data from a function: `RETURN` and `RETURN NEXT`.

40.6.1.1. `RETURN`

```
RETURN expression;
```

`RETURN` with an expression terminates the function and returns the value of *`expression`* to the caller. This form is used for PL/pgSQL functions that do not return a set.

In a function that returns a scalar type, the expression's result will automatically be cast into the function's return type as described for assignments. But to return a composite (row) value, you must write an expression delivering exactly the requested column set. This may require use of explicit casting.

If you declared the function with output parameters, write just `RETURN` with no expression. The current values of the output parameter variables will be returned.

If you declared the function to return `void`, a `RETURN` statement can be used to exit the function early; but do not write an expression following `RETURN`.

The return value of a function cannot be left undefined. If control reaches the end of the top-level block of the function without hitting a `RETURN` statement, a run-time error will occur. This restriction

does not apply to functions with output parameters and functions returning `void`, however. In those cases a `RETURN` statement is automatically executed if the top-level block finishes.

Some examples:

```
-- functions returning a scalar type
RETURN 1 + 2;
RETURN scalar_var;

-- functions returning a composite type
RETURN composite_type_var;
RETURN (1, 2, 'three'::text);  -- must cast columns to correct types
```

40.6.1.2. `RETURN NEXT` and `RETURN QUERY`

```
RETURN NEXT expression;
RETURN QUERY query;
RETURN QUERY EXECUTE command-string [ USING expression [, ... ] ];
```

When a PL/pgSQL function is declared to return `SETOF sometype`, the procedure to follow is slightly different. In that case, the individual items to return are specified by a sequence of `RETURN NEXT` or `RETURN QUERY` commands, and then a final `RETURN` command with no argument is used to indicate that the function has finished executing. `RETURN NEXT` can be used with both scalar and composite data types; with a composite result type, an entire "table" of results will be returned. `RETURN QUERY` appends the results of executing a query to the function's result set. `RETURN NEXT` and `RETURN QUERY` can be freely intermixed in a single set-returning function, in which case their results will be concatenated.

`RETURN NEXT` and `RETURN QUERY` do not actually return from the function — they simply append zero or more rows to the function's result set. Execution then continues with the next statement in the PL/pgSQL function. As successive `RETURN NEXT` or `RETURN QUERY` commands are executed, the result set is built up. A final `RETURN`, which should have no argument, causes control to exit the function (or you can just let control reach the end of the function).

`RETURN QUERY` has a variant `RETURN QUERY EXECUTE`, which specifies the query to be executed dynamically. Parameter expressions can be inserted into the computed query string via `USING`, in just the same way as in the `EXECUTE` command.

If you declared the function with output parameters, write just `RETURN NEXT` with no expression. On each execution, the current values of the output parameter variable(s) will be saved for eventual return as a row of the result. Note that you must declare the function as returning `SETOF record` when there are multiple output parameters, or `SETOF sometype` when there is just one output parameter of type *sometype*, in order to create a set-returning function with output parameters.

Here is an example of a function using `RETURN NEXT`:

```
CREATE TABLE foo (fooid INT, foosubid INT, fooname TEXT);
INSERT INTO foo VALUES (1, 2, 'three');
INSERT INTO foo VALUES (4, 5, 'six');

CREATE OR REPLACE FUNCTION get_all_foo() RETURNS SETOF foo AS
$BODY$
DECLARE
    r foo%rowtype;
BEGIN
```

```
    FOR r IN
        SELECT * FROM foo WHERE fooid > 0
    LOOP
        -- can do some processing here
        RETURN NEXT r; -- return current row of SELECT
    END LOOP;
    RETURN;
END
$BODY$
LANGUAGE plpgsql;

SELECT * FROM get_all_foo();
```

Here is an example of a function using `RETURN QUERY`:

```
CREATE FUNCTION get_available_flightid(date) RETURNS SETOF integer AS
$BODY$
BEGIN
    RETURN QUERY SELECT flightid
                   FROM flight
                  WHERE flightdate >= $1
                    AND flightdate < ($1 + 1);

    -- Since execution is not finished, we can check whether rows were returned
    -- and raise exception if not.
    IF NOT FOUND THEN
        RAISE EXCEPTION 'No flight at %.', $1;
    END IF;

    RETURN;
 END
$BODY$
LANGUAGE plpgsql;

-- Returns available flights or raises exception if there are no
-- available flights.
SELECT * FROM get_available_flightid(CURRENT_DATE);
```

Note: The current implementation of `RETURN NEXT` and `RETURN QUERY` stores the entire result set before returning from the function, as discussed above. That means that if a PL/pgSQL function produces a very large result set, performance might be poor: data will be written to disk to avoid memory exhaustion, but the function itself will not return until the entire result set has been generated. A future version of PL/pgSQL might allow users to define set-returning functions that do not have this limitation. Currently, the point at which data begins being written to disk is controlled by the work_mem configuration variable. Administrators who have sufficient memory to store larger result sets in memory should consider increasing this parameter.

40.6.2. Conditionals

IF and CASE statements let you execute alternative commands based on certain conditions. PL/pgSQL has three forms of IF:

- IF ... THEN
- IF ... THEN ... ELSE
- IF ... THEN ... ELSIF ... THEN ... ELSE

and two forms of CASE:

- CASE ... WHEN ... THEN ... ELSE ... END CASE
- CASE WHEN ... THEN ... ELSE ... END CASE

40.6.2.1. IF-THEN

```
IF boolean-expression THEN
    statements
END IF;
```

IF-THEN statements are the simplest form of IF. The statements between THEN and END IF will be executed if the condition is true. Otherwise, they are skipped.

Example:

```
IF v_user_id <> 0 THEN
    UPDATE users SET email = v_email WHERE user_id = v_user_id;
END IF;
```

40.6.2.2. IF-THEN-ELSE

```
IF boolean-expression THEN
    statements
ELSE
    statements
END IF;
```

IF-THEN-ELSE statements add to IF-THEN by letting you specify an alternative set of statements that should be executed if the condition is not true. (Note this includes the case where the condition evaluates to NULL.)

Examples:

```
IF parentid IS NULL OR parentid = ''
THEN
    RETURN fullname;
ELSE
    RETURN hp_true_filename(parentid) || '/' || fullname;
END IF;
```

```
IF v_count > 0 THEN
    INSERT INTO users_count (count) VALUES (v_count);
    RETURN 't';
ELSE
    RETURN 'f';
END IF;
```

40.6.2.3. IF-THEN-ELSIF

```
IF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
[ ELSIF boolean-expression THEN
    statements
    ...]]
[ ELSE
    statements ]
END IF;
```

Sometimes there are more than just two alternatives. IF-THEN-ELSIF provides a convenient method of checking several alternatives in turn. The IF conditions are tested successively until the first one that is true is found. Then the associated statement(s) are executed, after which control passes to the next statement after END IF. (Any subsequent IF conditions are *not* tested.) If none of the IF conditions is true, then the ELSE block (if any) is executed.

Here is an example:

```
IF number = 0 THEN
    result := 'zero';
ELSIF number > 0 THEN
    result := 'positive';
ELSIF number < 0 THEN
    result := 'negative';
ELSE
    -- hmm, the only other possibility is that number is null
    result := 'NULL';
END IF;
```

The key word ELSIF can also be spelled ELSEIF.

An alternative way of accomplishing the same task is to nest IF-THEN-ELSE statements, as in the following example:

```
IF demo_row.sex = 'm' THEN
    pretty_sex := 'man';
ELSE
    IF demo_row.sex = 'f' THEN
        pretty_sex := 'woman';
    END IF;
END IF;
```

However, this method requires writing a matching `END IF` for each `IF`, so it is much more cumbersome than using `ELSIF` when there are many alternatives.

40.6.2.4. Simple `CASE`

```
CASE search-expression
    WHEN expression [, expression [ ... ]] THEN
      statements
  [ WHEN expression [, expression [ ... ]] THEN
      statements
    ... ]
  [ ELSE
      statements ]
END CASE;
```

The simple form of `CASE` provides conditional execution based on equality of operands. The *`search-expression`* is evaluated (once) and successively compared to each *`expression`* in the `WHEN` clauses. If a match is found, then the corresponding *`statements`* are executed, and then control passes to the next statement after `END CASE`. (Subsequent `WHEN` expressions are not evaluated.) If no match is found, the `ELSE` *`statements`* are executed; but if `ELSE` is not present, then a `CASE_NOT_FOUND` exception is raised.

Here is a simple example:

```
CASE x
    WHEN 1, 2 THEN
        msg := 'one or two';
    ELSE
        msg := 'other value than one or two';
END CASE;
```

40.6.2.5. Searched `CASE`

```
CASE
    WHEN boolean-expression THEN
      statements
  [ WHEN boolean-expression THEN
      statements
    ... ]
  [ ELSE
      statements ]
END CASE;
```

The searched form of `CASE` provides conditional execution based on truth of Boolean expressions. Each `WHEN` clause's *`boolean-expression`* is evaluated in turn, until one is found that yields `true`. Then the corresponding *`statements`* are executed, and then control passes to the next statement after `END CASE`. (Subsequent `WHEN` expressions are not evaluated.) If no true result is found, the `ELSE` *`statements`* are executed; but if `ELSE` is not present, then a `CASE_NOT_FOUND` exception is raised.

Here is an example:

```
CASE
```

```
    WHEN x BETWEEN 0 AND 10 THEN
        msg := 'value is between zero and ten';
    WHEN x BETWEEN 11 AND 20 THEN
        msg := 'value is between eleven and twenty';
END CASE;
```

This form of CASE is entirely equivalent to IF-THEN-ELSIF, except for the rule that reaching an omitted ELSE clause results in an error rather than doing nothing.

40.6.3. Simple Loops

With the LOOP, EXIT, CONTINUE, WHILE, FOR, and FOREACH statements, you can arrange for your PL/pgSQL function to repeat a series of commands.

40.6.3.1. LOOP

```
[ <<label>> ]
LOOP
    statements
END LOOP [ label ];
```

LOOP defines an unconditional loop that is repeated indefinitely until terminated by an EXIT or RETURN statement. The optional *label* can be used by EXIT and CONTINUE statements within nested loops to specify which loop those statements refer to.

40.6.3.2. EXIT

```
EXIT [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the innermost loop is terminated and the statement following END LOOP is executed next. If *label* is given, it must be the label of the current or some outer level of nested loop or block. Then the named loop or block is terminated and control continues with the statement after the loop's/block's corresponding END.

If WHEN is specified, the loop exit occurs only if *boolean-expression* is true. Otherwise, control passes to the statement after EXIT.

EXIT can be used with all types of loops; it is not limited to use with unconditional loops.

When used with a BEGIN block, EXIT passes control to the next statement after the end of the block. Note that a label must be used for this purpose; an unlabeled EXIT is never considered to match a BEGIN block. (This is a change from pre-8.4 releases of PostgreSQL, which would allow an unlabeled EXIT to match a BEGIN block.)

Examples:

```
LOOP
    -- some computations
    IF count > 0 THEN
        EXIT;  -- exit loop
    END IF;
END LOOP;
```

```
LOOP
    -- some computations
    EXIT WHEN count > 0;  -- same result as previous example
END LOOP;

<<ablock>>
BEGIN
    -- some computations
    IF stocks > 100000 THEN
        EXIT ablock;  -- causes exit from the BEGIN block
    END IF;
    -- computations here will be skipped when stocks > 100000
END;
```

40.6.3.3. CONTINUE

```
CONTINUE [ label ] [ WHEN boolean-expression ];
```

If no *label* is given, the next iteration of the innermost loop is begun. That is, all statements remaining in the loop body are skipped, and control returns to the loop control expression (if any) to determine whether another loop iteration is needed. If *label* is present, it specifies the label of the loop whose execution will be continued.

If WHEN is specified, the next iteration of the loop is begun only if *boolean-expression* is true. Otherwise, control passes to the statement after CONTINUE.

CONTINUE can be used with all types of loops; it is not limited to use with unconditional loops.

Examples:

```
LOOP
    -- some computations
    EXIT WHEN count > 100;
    CONTINUE WHEN count < 50;
    -- some computations for count IN [50 .. 100]
END LOOP;
```

40.6.3.4. WHILE

```
[ <<label>> ]
WHILE boolean-expression LOOP
    statements
END LOOP [ label ];
```

The WHILE statement repeats a sequence of statements so long as the *boolean-expression* evaluates to true. The expression is checked just before each entry to the loop body.

For example:

```
WHILE amount_owed > 0 AND gift_certificate_balance > 0 LOOP
    -- some computations here
```

```
END LOOP;

WHILE NOT done LOOP
    -- some computations here
END LOOP;
```

40.6.3.5. FOR (Integer Variant)

```
[ <<label>> ]
FOR name IN [ REVERSE ] expression .. expression [ BY expression ] LOOP
    statements
END LOOP [ label ];
```

This form of FOR creates a loop that iterates over a range of integer values. The variable *name* is automatically defined as type integer and exists only inside the loop (any existing definition of the variable name is ignored within the loop). The two expressions giving the lower and upper bound of the range are evaluated once when entering the loop. If the BY clause isn't specified the iteration step is 1, otherwise it's the value specified in the BY clause, which again is evaluated once on loop entry. If REVERSE is specified then the step value is subtracted, rather than added, after each iteration.

Some examples of integer FOR loops:

```
FOR i IN 1..10 LOOP
    -- i will take on the values 1,2,3,4,5,6,7,8,9,10 within the loop
END LOOP;

FOR i IN REVERSE 10..1 LOOP
    -- i will take on the values 10,9,8,7,6,5,4,3,2,1 within the loop
END LOOP;

FOR i IN REVERSE 10..1 BY 2 LOOP
    -- i will take on the values 10,8,6,4,2 within the loop
END LOOP;
```

If the lower bound is greater than the upper bound (or less than, in the REVERSE case), the loop body is not executed at all. No error is raised.

If a *label* is attached to the FOR loop then the integer loop variable can be referenced with a qualified name, using that *label*.

40.6.4. Looping Through Query Results

Using a different type of FOR loop, you can iterate through the results of a query and manipulate that data accordingly. The syntax is:

```
[ <<label>> ]
FOR target IN query LOOP
    statements
END LOOP [ label ];
```

The *target* is a record variable, row variable, or comma-separated list of scalar variables. The *target* is successively assigned each row resulting from the *query* and the loop body is executed for each row. Here is an example:

```
CREATE FUNCTION cs_refresh_mviews() RETURNS integer AS $$
DECLARE
    mviews RECORD;
BEGIN
    RAISE NOTICE 'Refreshing materialized views...';

    FOR mviews IN SELECT * FROM cs_materialized_views ORDER BY sort_key LOOP

        -- Now "mviews" has one record from cs_materialized_views

        RAISE NOTICE 'Refreshing materialized view %s ...', quote_ident(mviews.mv_name);
        EXECUTE 'TRUNCATE TABLE ' || quote_ident(mviews.mv_name);
        EXECUTE 'INSERT INTO '
                  || quote_ident(mviews.mv_name) || ' '
                  || mviews.mv_query;
    END LOOP;

    RAISE NOTICE 'Done refreshing materialized views.';
    RETURN 1;
END;
$$ LANGUAGE plpgsql;
```

If the loop is terminated by an `EXIT` statement, the last assigned row value is still accessible after the loop.

The *query* used in this type of `FOR` statement can be any SQL command that returns rows to the caller: `SELECT` is the most common case, but you can also use `INSERT`, `UPDATE`, or `DELETE` with a `RETURNING` clause. Some utility commands such as `EXPLAIN` will work too.

PL/pgSQL variables are substituted into the query text, and the query plan is cached for possible re-use, as discussed in detail in Section 40.10.1 and Section 40.10.2.

The `FOR-IN-EXECUTE` statement is another way to iterate over rows:

```
[ <<label>> ]
FOR target IN EXECUTE text_expression [ USING expression [, ... ] ] LOOP
    statements
END LOOP [ label ];
```

This is like the previous form, except that the source query is specified as a string expression, which is evaluated and replanned on each entry to the `FOR` loop. This allows the programmer to choose the speed of a preplanned query or the flexibility of a dynamic query, just as with a plain `EXECUTE` statement. As with `EXECUTE`, parameter values can be inserted into the dynamic command via `USING`.

Another way to specify the query whose results should be iterated through is to declare it as a cursor. This is described in Section 40.7.4.

40.6.5. Looping Through Arrays

The `FOREACH` loop is much like a `FOR` loop, but instead of iterating through the rows returned by a SQL query, it iterates through the elements of an array value. (In general, `FOREACH` is meant for loop-

ing through components of a composite-valued expression; variants for looping through composites besides arrays may be added in future.) The FOREACH statement to loop over an array is:

```
[ <<label>> ]
FOREACH target [ SLICE number ] IN ARRAY expression LOOP
    statements
END LOOP [ label ];
```

Without SLICE, or if SLICE 0 is specified, the loop iterates through individual elements of the array produced by evaluating the *expression*. The *target* variable is assigned each element value in sequence, and the loop body is executed for each element. Here is an example of looping through the elements of an integer array:

```
CREATE FUNCTION sum(int[]) RETURNS int8 AS $$
DECLARE
  s int8 := 0;
  x int;
BEGIN
  FOREACH x IN ARRAY $1
  LOOP
    s := s + x;
  END LOOP;
  RETURN s;
END;
$$ LANGUAGE plpgsql;
```

The elements are visited in storage order, regardless of the number of array dimensions. Although the *target* is usually just a single variable, it can be a list of variables when looping through an array of composite values (records). In that case, for each array element, the variables are assigned from successive columns of the composite value.

With a positive SLICE value, FOREACH iterates through slices of the array rather than single elements. The SLICE value must be an integer constant not larger than the number of dimensions of the array. The *target* variable must be an array, and it receives successive slices of the array value, where each slice is of the number of dimensions specified by SLICE. Here is an example of iterating through one-dimensional slices:

```
CREATE FUNCTION scan_rows(int[]) RETURNS void AS $$
DECLARE
  x int[];
BEGIN
  FOREACH x SLICE 1 IN ARRAY $1
  LOOP
    RAISE NOTICE 'row = %', x;
  END LOOP;
END;
$$ LANGUAGE plpgsql;

SELECT scan_rows(ARRAY[[1,2,3],[4,5,6],[7,8,9],[10,11,12]]);

NOTICE:  row = {1,2,3}
NOTICE:  row = {4,5,6}
NOTICE:  row = {7,8,9}
NOTICE:  row = {10,11,12}
```

40.6.6. Trapping Errors

By default, any error occurring in a PL/pgSQL function aborts execution of the function, and indeed of the surrounding transaction as well. You can trap errors and recover from them by using a BEGIN block with an EXCEPTION clause. The syntax is an extension of the normal syntax for a BEGIN block:

```
[ <<label>> ]
[ DECLARE
    declarations ]
BEGIN
    statements
EXCEPTION
    WHEN condition [ OR condition ... ] THEN
        handler_statements
    [ WHEN condition [ OR condition ... ] THEN
          handler_statements
      ... ]
END;
```

If no error occurs, this form of block simply executes all the *statements*, and then control passes to the next statement after END. But if an error occurs within the *statements*, further processing of the *statements* is abandoned, and control passes to the EXCEPTION list. The list is searched for the first *condition* matching the error that occurred. If a match is found, the corresponding *handler_statements* are executed, and then control passes to the next statement after END. If no match is found, the error propagates out as though the EXCEPTION clause were not there at all: the error can be caught by an enclosing block with EXCEPTION, or if there is none it aborts processing of the function.

The *condition* names can be any of those shown in Appendix A. A category name matches any error within its category. The special condition name OTHERS matches every error type except QUERY_CANCELED. (It is possible, but often unwise, to trap QUERY_CANCELED by name.) Condition names are not case-sensitive. Also, an error condition can be specified by SQLSTATE code; for example these are equivalent:

```
WHEN division_by_zero THEN ...
WHEN SQLSTATE '22012' THEN ...
```

If a new error occurs within the selected *handler_statements*, it cannot be caught by this EXCEPTION clause, but is propagated out. A surrounding EXCEPTION clause could catch it.

When an error is caught by an EXCEPTION clause, the local variables of the PL/pgSQL function remain as they were when the error occurred, but all changes to persistent database state within the block are rolled back. As an example, consider this fragment:

```
INSERT INTO mytab(firstname, lastname) VALUES('Tom', 'Jones');
BEGIN
    UPDATE mytab SET firstname = 'Joe' WHERE lastname = 'Jones';
    x := x + 1;
    y := x / 0;
EXCEPTION
```

```
    WHEN division_by_zero THEN
        RAISE NOTICE 'caught division_by_zero';
        RETURN x;
END;
```

When control reaches the assignment to `y`, it will fail with a `division_by_zero` error. This will be caught by the `EXCEPTION` clause. The value returned in the `RETURN` statement will be the incremented value of `x`, but the effects of the `UPDATE` command will have been rolled back. The `INSERT` command preceding the block is not rolled back, however, so the end result is that the database contains `Tom Jones` not `Joe Jones`.

> **Tip:** A block containing an `EXCEPTION` clause is significantly more expensive to enter and exit than a block without one. Therefore, don't use `EXCEPTION` without need.

Example 40-2. Exceptions with `UPDATE/INSERT`

This example uses exception handling to perform either `UPDATE` or `INSERT`, as appropriate:

```
CREATE TABLE db (a INT PRIMARY KEY, b TEXT);

CREATE FUNCTION merge_db(key INT, data TEXT) RETURNS VOID AS
$$
BEGIN
    LOOP
        -- first try to update the key
        UPDATE db SET b = data WHERE a = key;
        IF found THEN
            RETURN;
        END IF;
        -- not there, so try to insert the key
        -- if someone else inserts the same key concurrently,
        -- we could get a unique-key failure
        BEGIN
            INSERT INTO db(a,b) VALUES (key, data);
            RETURN;
        EXCEPTION WHEN unique_violation THEN
            -- Do nothing, and loop to try the UPDATE again.
        END;
    END LOOP;
END;
$$
LANGUAGE plpgsql;

SELECT merge_db(1, 'david');
SELECT merge_db(1, 'dennis');
```

This coding assumes the `unique_violation` error is caused by the `INSERT`, and not by, say, an `INSERT` in a trigger function on the table. It might also misbehave if there is more than one unique index on the table, since it will retry the operation regardless of which index caused the error. More safety could be had by using the features discussed next to check that the trapped error was the one expected.

40.6.6.1. Obtaining Information About an Error

Exception handlers frequently need to identify the specific error that occurred. There are two ways to get information about the current exception in PL/pgSQL: special variables and the `GET STACKED DIAGNOSTICS` command.

Within an exception handler, the special variable `SQLSTATE` contains the error code that corresponds to the exception that was raised (refer to Table A-1 for a list of possible error codes). The special variable `SQLERRM` contains the error message associated with the exception. These variables are undefined outside exception handlers.

Within an exception handler, one may also retrieve information about the current exception by using the `GET STACKED DIAGNOSTICS` command, which has the form:

```
GET STACKED DIAGNOSTICS variable { = | := } item [ , ... ];
```

Each *item* is a key word identifying a status value to be assigned to the specified variable (which should be of the right data type to receive it). The currently available status items are shown in Table 40-1.

Table 40-1. Error Diagnostics Values

Name	Type	Description
RETURNED_SQLSTATE	text	the SQLSTATE error code of the exception
COLUMN_NAME	text	the name of the column related to exception
CONSTRAINT_NAME	text	the name of the constraint related to exception
PG_DATATYPE_NAME	text	the name of the data type related to exception
MESSAGE_TEXT	text	the text of the exception's primary message
TABLE_NAME	text	the name of the table related to exception
SCHEMA_NAME	text	the name of the schema related to exception
PG_EXCEPTION_DETAIL	text	the text of the exception's detail message, if any
PG_EXCEPTION_HINT	text	the text of the exception's hint message, if any
PG_EXCEPTION_CONTEXT	text	line(s) of text describing the call stack

If the exception did not set a value for an item, an empty string will be returned.

Here is an example:

```
DECLARE
  text_var1 text;
  text_var2 text;
  text_var3 text;
BEGIN
```

```
  -- some processing which might cause an exception
  ...
EXCEPTION WHEN OTHERS THEN
  GET STACKED DIAGNOSTICS text_var1 = MESSAGE_TEXT,
                          text_var2 = PG_EXCEPTION_DETAIL,
                          text_var3 = PG_EXCEPTION_HINT;
END;
```

40.6.7. Obtaining Current Execution Information

The `GET [ CURRENT ] DIAGNOSTICS` command retrieves information about current execution state (whereas the `GET STACKED DIAGNOSTICS` command discussed above reports information about the execution state as of a previous error). This command has the form:

```
GET [ CURRENT ] DIAGNOSTICS variable { = | := } item [ , ... ];
```

Currently only one information item is supported. Status item `PG_CONTEXT` will return a text string with line(s) of text describing the call stack. The first line refers to the current function and currently executing `GET DIAGNOSTICS` command. The second and any subsequent lines refer to calling functions further up the call stack. For example:

```
CREATE OR REPLACE FUNCTION outer_func() RETURNS integer AS $$
BEGIN
  RETURN inner_func();
END;
$$ LANGUAGE plpgsql;

CREATE OR REPLACE FUNCTION inner_func() RETURNS integer AS $$
DECLARE
  stack text;
BEGIN
  GET DIAGNOSTICS stack = PG_CONTEXT;
  RAISE NOTICE E'--- Call Stack ---\n%', stack;
  RETURN 1;
END;
$$ LANGUAGE plpgsql;

SELECT outer_func();

NOTICE:  --- Call Stack ---
PL/pgSQL function inner_func() line 5 at GET DIAGNOSTICS
PL/pgSQL function outer_func() line 3 at RETURN
CONTEXT:  PL/pgSQL function outer_func() line 3 at RETURN
 outer_func
 ------------
           1
(1 row)
```

40.7. Cursors

Rather than executing a whole query at once, it is possible to set up a *cursor* that encapsulates the query, and then read the query result a few rows at a time. One reason for doing this is to avoid memory overrun when the result contains a large number of rows. (However, PL/pgSQL users do not normally need to worry about that, since FOR loops automatically use a cursor internally to avoid memory problems.) A more interesting usage is to return a reference to a cursor that a function has created, allowing the caller to read the rows. This provides an efficient way to return large row sets from functions.

40.7.1. Declaring Cursor Variables

All access to cursors in PL/pgSQL goes through cursor variables, which are always of the special data type refcursor. One way to create a cursor variable is just to declare it as a variable of type refcursor. Another way is to use the cursor declaration syntax, which in general is:

```
name [ [ NO ] SCROLL ] CURSOR [ ( arguments ) ] FOR query;
```

(FOR can be replaced by IS for Oracle compatibility.) If SCROLL is specified, the cursor will be capable of scrolling backward; if NO SCROLL is specified, backward fetches will be rejected; if neither specification appears, it is query-dependent whether backward fetches will be allowed. *arguments*, if specified, is a comma-separated list of pairs *name datatype* that define names to be replaced by parameter values in the given query. The actual values to substitute for these names will be specified later, when the cursor is opened.

Some examples:

```
DECLARE
    curs1 refcursor;
    curs2 CURSOR FOR SELECT * FROM tenk1;
    curs3 CURSOR (key integer) FOR SELECT * FROM tenk1 WHERE unique1 = key;
```

All three of these variables have the data type refcursor, but the first can be used with any query, while the second has a fully specified query already *bound* to it, and the last has a parameterized query bound to it. (key will be replaced by an integer parameter value when the cursor is opened.) The variable curs1 is said to be *unbound* since it is not bound to any particular query.

40.7.2. Opening Cursors

Before a cursor can be used to retrieve rows, it must be *opened*. (This is the equivalent action to the SQL command DECLARE CURSOR.) PL/pgSQL has three forms of the OPEN statement, two of which use unbound cursor variables while the third uses a bound cursor variable.

> **Note:** Bound cursor variables can also be used without explicitly opening the cursor, via the FOR statement described in Section 40.7.4.

40.7.2.1. OPEN FOR *query*

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR query;
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query must be a `SELECT`, or something else that returns rows (such as `EXPLAIN`). The query is treated in the same way as other SQL commands in PL/pgSQL: PL/pgSQL variable names are substituted, and the query plan is cached for possible reuse. When a PL/pgSQL variable is substituted into the cursor query, the value that is substituted is the one it has at the time of the `OPEN`; subsequent changes to the variable will not affect the cursor's behavior. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:

```
OPEN curs1 FOR SELECT * FROM foo WHERE key = mykey;
```

40.7.2.2. `OPEN FOR EXECUTE`

```
OPEN unbound_cursorvar [ [ NO ] SCROLL ] FOR EXECUTE query_string
                                        [ USING expression [, ... ] ];
```

The cursor variable is opened and given the specified query to execute. The cursor cannot be open already, and it must have been declared as an unbound cursor variable (that is, as a simple `refcursor` variable). The query is specified as a string expression, in the same way as in the `EXECUTE` command. As usual, this gives flexibility so the query plan can vary from one run to the next (see Section 40.10.2), and it also means that variable substitution is not done on the command string. As with `EXECUTE`, parameter values can be inserted into the dynamic command via `USING`. The `SCROLL` and `NO SCROLL` options have the same meanings as for a bound cursor.

An example:

```
OPEN curs1 FOR EXECUTE 'SELECT * FROM ' || quote_ident(tabname)
                                        || ' WHERE col1 = $1' USING keyvalue;
```

In this example, the table name is inserted into the query textually, so use of `quote_ident()` is recommended to guard against SQL injection. The comparison value for `col1` is inserted via a `USING` parameter, so it needs no quoting.

40.7.2.3. Opening a Bound Cursor

```
OPEN bound_cursorvar [ ( [ argument_name := ] argument_value [, ...] ) ];
```

This form of `OPEN` is used to open a cursor variable whose query was bound to it when it was declared. The cursor cannot be open already. A list of actual argument value expressions must appear if and only if the cursor was declared to take arguments. These values will be substituted in the query.

The query plan for a bound cursor is always considered cacheable; there is no equivalent of `EXECUTE` in this case. Notice that `SCROLL` and `NO SCROLL` cannot be specified in `OPEN`, as the cursor's scrolling behavior was already determined.

Argument values can be passed using either *positional* or *named* notation. In positional notation, all arguments are specified in order. In named notation, each argument's name is specified using `:=` to separate it from the argument expression. Similar to calling functions, described in Section 4.3, it is also allowed to mix positional and named notation.

Examples (these use the cursor declaration examples above):

```
OPEN curs2;
OPEN curs3(42);
OPEN curs3(key := 42);
```

Because variable substitution is done on a bound cursor's query, there are really two ways to pass values into the cursor: either with an explicit argument to OPEN, or implicitly by referencing a PL/pgSQL variable in the query. However, only variables declared before the bound cursor was declared will be substituted into it. In either case the value to be passed is determined at the time of the OPEN. For example, another way to get the same effect as the curs3 example above is

```
DECLARE
    key integer;
    curs4 CURSOR FOR SELECT * FROM tenk1 WHERE unique1 = key;
BEGIN
    key := 42;
    OPEN curs4;
```

40.7.3. Using Cursors

Once a cursor has been opened, it can be manipulated with the statements described here.

These manipulations need not occur in the same function that opened the cursor to begin with. You can return a refcursor value out of a function and let the caller operate on the cursor. (Internally, a refcursor value is simply the string name of a so-called portal containing the active query for the cursor. This name can be passed around, assigned to other refcursor variables, and so on, without disturbing the portal.)

All portals are implicitly closed at transaction end. Therefore a refcursor value is usable to reference an open cursor only until the end of the transaction.

40.7.3.1. FETCH

```
FETCH [ direction { FROM | IN } ] cursor INTO target;
```

FETCH retrieves the next row from the cursor into a target, which might be a row variable, a record variable, or a comma-separated list of simple variables, just like SELECT INTO. If there is no next row, the target is set to NULL(s). As with SELECT INTO, the special variable FOUND can be checked to see whether a row was obtained or not.

The *direction* clause can be any of the variants allowed in the SQL FETCH command except the ones that can fetch more than one row; namely, it can be NEXT, PRIOR, FIRST, LAST, ABSOLUTE *count*, RELATIVE *count*, FORWARD, or BACKWARD. Omitting *direction* is the same as specifying NEXT. *direction* values that require moving backward are likely to fail unless the cursor was declared or opened with the SCROLL option.

cursor must be the name of a refcursor variable that references an open cursor portal.

Examples:

```
FETCH curs1 INTO rowvar;
FETCH curs2 INTO foo, bar, baz;
```

```
FETCH LAST FROM curs3 INTO x, y;
FETCH RELATIVE -2 FROM curs4 INTO x;
```

40.7.3.2. MOVE

```
MOVE [ direction { FROM | IN } ] cursor;
```

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only repositions the cursor and does not return the row moved to. As with SELECT INTO, the special variable FOUND can be checked to see whether there was a next row to move to.

The *direction* clause can be any of the variants allowed in the SQL FETCH command, namely NEXT, PRIOR, FIRST, LAST, ABSOLUTE *count*, RELATIVE *count*, ALL, FORWARD [*count* | ALL], or BACKWARD [*count* | ALL]. Omitting *direction* is the same as specifying NEXT. *direction* values that require moving backward are likely to fail unless the cursor was declared or opened with the SCROLL option.

Examples:

```
MOVE curs1;
MOVE LAST FROM curs3;
MOVE RELATIVE -2 FROM curs4;
MOVE FORWARD 2 FROM curs4;
```

40.7.3.3. UPDATE/DELETE WHERE CURRENT OF

```
UPDATE table SET ... WHERE CURRENT OF cursor;
DELETE FROM table WHERE CURRENT OF cursor;
```

When a cursor is positioned on a table row, that row can be updated or deleted using the cursor to identify the row. There are restrictions on what the cursor's query can be (in particular, no grouping) and it's best to use FOR UPDATE in the cursor. For more information see the DECLARE reference page.

An example:

```
UPDATE foo SET dataval = myval WHERE CURRENT OF curs1;
```

40.7.3.4. CLOSE

```
CLOSE cursor;
```

CLOSE closes the portal underlying an open cursor. This can be used to release resources earlier than end of transaction, or to free up the cursor variable to be opened again.

An example:

```
CLOSE curs1;
```

40.7.3.5. Returning Cursors

PL/pgSQL functions can return cursors to the caller. This is useful to return multiple rows or columns, especially with very large result sets. To do this, the function opens the cursor and returns the cursor name to the caller (or simply opens the cursor using a portal name specified by or otherwise known to the caller). The caller can then fetch rows from the cursor. The cursor can be closed by the caller, or it will be closed automatically when the transaction closes.

The portal name used for a cursor can be specified by the programmer or automatically generated. To specify a portal name, simply assign a string to the `refcursor` variable before opening it. The string value of the `refcursor` variable will be used by `OPEN` as the name of the underlying portal. However, if the `refcursor` variable is null, `OPEN` automatically generates a name that does not conflict with any existing portal, and assigns it to the `refcursor` variable.

> **Note:** A bound cursor variable is initialized to the string value representing its name, so that the portal name is the same as the cursor variable name, unless the programmer overrides it by assignment before opening the cursor. But an unbound cursor variable defaults to the null value initially, so it will receive an automatically-generated unique name, unless overridden.

The following example shows one way a cursor name can be supplied by the caller:

```
CREATE TABLE test (col text);
INSERT INTO test VALUES ('123');

CREATE FUNCTION reffunc(refcursor) RETURNS refcursor AS '
BEGIN
    OPEN $1 FOR SELECT col FROM test;
    RETURN $1;
END;
' LANGUAGE plpgsql;

BEGIN;
SELECT reffunc('funccursor');
FETCH ALL IN funccursor;
COMMIT;
```

The following example uses automatic cursor name generation:

```
CREATE FUNCTION reffunc2() RETURNS refcursor AS '
DECLARE
    ref refcursor;
BEGIN
    OPEN ref FOR SELECT col FROM test;
    RETURN ref;
END;
' LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;
SELECT reffunc2();
```

```
      reffunc2
--------------------
 <unnamed cursor 1>
(1 row)

FETCH ALL IN "<unnamed cursor 1>";
COMMIT;
```

The following example shows one way to return multiple cursors from a single function:

```
CREATE FUNCTION myfunc(refcursor, refcursor) RETURNS SETOF refcursor AS $$
BEGIN
    OPEN $1 FOR SELECT * FROM table_1;
    RETURN NEXT $1;
    OPEN $2 FOR SELECT * FROM table_2;
    RETURN NEXT $2;
END;
$$ LANGUAGE plpgsql;

-- need to be in a transaction to use cursors.
BEGIN;

SELECT * FROM myfunc('a', 'b');

FETCH ALL FROM a;
FETCH ALL FROM b;
COMMIT;
```

40.7.4. Looping Through a Cursor's Result

There is a variant of the `FOR` statement that allows iterating through the rows returned by a cursor. The syntax is:

```
[ <<label>> ]
FOR recordvar IN bound_cursorvar [ ( [ argument_name := ] argument_value [, ...] ) ] LOOP
    statements
END LOOP [ label ];
```

The cursor variable must have been bound to some query when it was declared, and it *cannot* be open already. The `FOR` statement automatically opens the cursor, and it closes the cursor again when the loop exits. A list of actual argument value expressions must appear if and only if the cursor was declared to take arguments. These values will be substituted in the query, in just the same way as during an `OPEN` (see Section 40.7.2.3).

The variable *recordvar* is automatically defined as type `record` and exists only inside the loop (any existing definition of the variable name is ignored within the loop). Each row returned by the cursor is successively assigned to this record variable and the loop body is executed.

40.8. Errors and Messages

Use the RAISE statement to report messages and raise errors.

```
RAISE [ level ] 'format' [, expression [, ... ]] [ USING option = expression [, ... ] ];
RAISE [ level ] condition_name [ USING option = expression [, ... ] ];
RAISE [ level ] SQLSTATE 'sqlstate' [ USING option = expression [, ... ] ];
RAISE [ level ] USING option = expression [, ... ];
RAISE ;
```

The *level* option specifies the error severity. Allowed levels are DEBUG, LOG, INFO, NOTICE, WARNING, and EXCEPTION, with EXCEPTION being the default. EXCEPTION raises an error (which normally aborts the current transaction); the other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log_min_messages and client_min_messages configuration variables. See Chapter 18 for more information.

After *level* if any, you can write a *format* (which must be a simple string literal, not an expression). The format string specifies the error message text to be reported. The format string can be followed by optional argument expressions to be inserted into the message. Inside the format string, % is replaced by the string representation of the next optional argument's value. Write %% to emit a literal %.

In this example, the value of v_job_id will replace the % in the string:

```
RAISE NOTICE 'Calling cs_create_job(%)', v_job_id;
```

You can attach additional information to the error report by writing USING followed by *option* = *expression* items. Each *expression* can be any string-valued expression. The allowed *option* key words are:

MESSAGE

Sets the error message text. This option can't be used in the form of RAISE that includes a format string before USING.

DETAIL

Supplies an error detail message.

HINT

Supplies a hint message.

ERRCODE

Specifies the error code (SQLSTATE) to report, either by condition name, as shown in Appendix A, or directly as a five-character SQLSTATE code.

COLUMN
CONSTRAINT
DATATYPE
TABLE
SCHEMA

Supplies the name of a related object.

This example will abort the transaction with the given error message and hint:

```
RAISE EXCEPTION 'Nonexistent ID --> %', user_id
      USING HINT = 'Please check your user ID';
```

These two examples show equivalent ways of setting the SQLSTATE:

```
RAISE 'Duplicate user ID: %', user_id USING ERRCODE = 'unique_violation';
RAISE 'Duplicate user ID: %', user_id USING ERRCODE = '23505';
```

There is a second `RAISE` syntax in which the main argument is the condition name or SQLSTATE to be reported, for example:

```
RAISE division_by_zero;
RAISE SQLSTATE '22012';
```

In this syntax, `USING` can be used to supply a custom error message, detail, or hint. Another way to do the earlier example is

```
RAISE unique_violation USING MESSAGE = 'Duplicate user ID: ' || user_id;
```

Still another variant is to write `RAISE USING` or `RAISE` *`level`* `USING` and put everything else into the `USING` list.

The last variant of `RAISE` has no parameters at all. This form can only be used inside a `BEGIN` block's `EXCEPTION` clause; it causes the error currently being handled to be re-thrown.

> **Note:** Before PostgreSQL 9.1, `RAISE` without parameters was interpreted as re-throwing the error from the block containing the active exception handler. Thus an `EXCEPTION` clause nested within that handler could not catch it, even if the `RAISE` was within the nested `EXCEPTION` clause's block. This was deemed surprising as well as being incompatible with Oracle's PL/SQL.

If no condition name nor SQLSTATE is specified in a `RAISE EXCEPTION` command, the default is to use `RAISE_EXCEPTION` (`P0001`). If no message text is specified, the default is to use the condition name or SQLSTATE as message text.

> **Note:** When specifying an error code by SQLSTATE code, you are not limited to the predefined error codes, but can select any error code consisting of five digits and/or upper-case ASCII letters, other than `00000`. It is recommended that you avoid throwing error codes that end in three zeroes, because these are category codes and can only be trapped by trapping the whole category.

40.9. Trigger Procedures

40.9.1. Triggers on Data Changes

PL/pgSQL can be used to define trigger procedures. A trigger procedure is created with the `CREATE FUNCTION` command, declaring it as a function with no arguments and a return type of `trigger`.

Note that the function must be declared with no arguments even if it expects to receive arguments specified in `CREATE TRIGGER` — trigger arguments are passed via `TG_ARGV`, as described below.

When a PL/pgSQL function is called as a trigger, several special variables are created automatically in the top-level block. They are:

`NEW`

Data type `RECORD`; variable holding the new database row for `INSERT`/`UPDATE` operations in row-level triggers. This variable is unassigned in statement-level triggers and for `DELETE` operations.

`OLD`

Data type `RECORD`; variable holding the old database row for `UPDATE`/`DELETE` operations in row-level triggers. This variable is unassigned in statement-level triggers and for `INSERT` operations.

`TG_NAME`

Data type `name`; variable that contains the name of the trigger actually fired.

`TG_WHEN`

Data type `text`; a string of `BEFORE`, `AFTER`, or `INSTEAD OF`, depending on the trigger's definition.

`TG_LEVEL`

Data type `text`; a string of either `ROW` or `STATEMENT` depending on the trigger's definition.

`TG_OP`

Data type `text`; a string of `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` telling for which operation the trigger was fired.

`TG_RELID`

Data type `oid`; the object ID of the table that caused the trigger invocation.

`TG_RELNAME`

Data type `name`; the name of the table that caused the trigger invocation. This is now deprecated, and could disappear in a future release. Use `TG_TABLE_NAME` instead.

`TG_TABLE_NAME`

Data type `name`; the name of the table that caused the trigger invocation.

`TG_TABLE_SCHEMA`

Data type `name`; the name of the schema of the table that caused the trigger invocation.

`TG_NARGS`

Data type `integer`; the number of arguments given to the trigger procedure in the `CREATE TRIGGER` statement.

`TG_ARGV[]`

Data type array of `text`; the arguments from the `CREATE TRIGGER` statement. The index counts from 0. Invalid indexes (less than 0 or greater than or equal to `tg_nargs`) result in a null value.

A trigger function must return either `NULL` or a record/row value having exactly the structure of the table the trigger was fired for.

Row-level triggers fired BEFORE can return null to signal the trigger manager to skip the rest of the operation for this row (i.e., subsequent triggers are not fired, and the INSERT/UPDATE/DELETE does not occur for this row). If a nonnull value is returned then the operation proceeds with that row value. Returning a row value different from the original value of NEW alters the row that will be inserted or updated. Thus, if the trigger function wants the triggering action to succeed normally without altering the row value, NEW (or a value equal thereto) has to be returned. To alter the row to be stored, it is possible to replace single values directly in NEW and return the modified NEW, or to build a complete new record/row to return. In the case of a before-trigger on DELETE, the returned value has no direct effect, but it has to be nonnull to allow the trigger action to proceed. Note that NEW is null in DELETE triggers, so returning that is usually not sensible. The usual idiom in DELETE triggers is to return OLD.

INSTEAD OF triggers (which are always row-level triggers, and may only be used on views) can return null to signal that they did not perform any updates, and that the rest of the operation for this row should be skipped (i.e., subsequent triggers are not fired, and the row is not counted in the rows-affected status for the surrounding INSERT/UPDATE/DELETE). Otherwise a nonnull value should be returned, to signal that the trigger performed the requested operation. For INSERT and UPDATE operations, the return value should be NEW, which the trigger function may modify to support INSERT RETURNING and UPDATE RETURNING (this will also affect the row value passed to any subsequent triggers). For DELETE operations, the return value should be OLD.

The return value of a row-level trigger fired AFTER or a statement-level trigger fired BEFORE or AFTER is always ignored; it might as well be null. However, any of these types of triggers might still abort the entire operation by raising an error.

Example 40-3 shows an example of a trigger procedure in PL/pgSQL.

Example 40-3. A PL/pgSQL Trigger Procedure

This example trigger ensures that any time a row is inserted or updated in the table, the current user name and time are stamped into the row. And it checks that an employee's name is given and that the salary is a positive value.

```
CREATE TABLE emp (
    empname text,
    salary integer,
    last_date timestamp,
    last_user text
);

CREATE FUNCTION emp_stamp() RETURNS trigger AS $emp_stamp$
    BEGIN
        -- Check that empname and salary are given
        IF NEW.empname IS NULL THEN
            RAISE EXCEPTION 'empname cannot be null';
        END IF;
        IF NEW.salary IS NULL THEN
            RAISE EXCEPTION '% cannot have null salary', NEW.empname;
        END IF;

        -- Who works for us when she must pay for it?
        IF NEW.salary < 0 THEN
            RAISE EXCEPTION '% cannot have a negative salary', NEW.empname;
        END IF;

        -- Remember who changed the payroll when
        NEW.last_date := current_timestamp;
        NEW.last_user := current_user;
```

```
        RETURN NEW;
    END;
$emp_stamp$ LANGUAGE plpgsql;

CREATE TRIGGER emp_stamp BEFORE INSERT OR UPDATE ON emp
    FOR EACH ROW EXECUTE PROCEDURE emp_stamp();
```

Another way to log changes to a table involves creating a new table that holds a row for each insert, update, or delete that occurs. This approach can be thought of as auditing changes to a table. Example 40-4 shows an example of an audit trigger procedure in PL/pgSQL.

Example 40-4. A PL/pgSQL Trigger Procedure For Auditing

This example trigger ensures that any insert, update or delete of a row in the `emp` table is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are stamped into the row, together with the type of operation performed on it.

```
CREATE TABLE emp (
    empname           text NOT NULL,
    salary            integer
);

CREATE TABLE emp_audit(
    operation         char(1)   NOT NULL,
    stamp             timestamp NOT NULL,
    userid            text      NOT NULL,
    empname           text      NOT NULL,
    salary integer
);

CREATE OR REPLACE FUNCTION process_emp_audit() RETURNS TRIGGER AS $emp_audit$
    BEGIN
        --
        -- Create a row in emp_audit to reflect the operation performed on emp,
        -- make use of the special variable TG_OP to work out the operation.
        --
        IF (TG_OP = 'DELETE') THEN
            INSERT INTO emp_audit SELECT 'D', now(), user, OLD.*;
            RETURN OLD;
        ELSIF (TG_OP = 'UPDATE') THEN
            INSERT INTO emp_audit SELECT 'U', now(), user, NEW.*;
            RETURN NEW;
        ELSIF (TG_OP = 'INSERT') THEN
            INSERT INTO emp_audit SELECT 'I', now(), user, NEW.*;
            RETURN NEW;
        END IF;
        RETURN NULL; -- result is ignored since this is an AFTER trigger
    END;
$emp_audit$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit
AFTER INSERT OR UPDATE OR DELETE ON emp
    FOR EACH ROW EXECUTE PROCEDURE process_emp_audit();
```

A variation of the previous example uses a view joining the main table to the audit table, to show when each entry was last modified. This approach still records the full audit trail of changes to the table, but also presents a simplified view of the audit trail, showing just the last modified timestamp

derived from the audit trail for each entry. Example 40-5 shows an example of an audit trigger on a view in PL/pgSQL.

Example 40-5. A PL/pgSQL View Trigger Procedure For Auditing

This example uses a trigger on the view to make it updatable, and ensure that any insert, update or delete of a row in the view is recorded (i.e., audited) in the `emp_audit` table. The current time and user name are recorded, together with the type of operation performed, and the view displays the last modified time of each row.

```
CREATE TABLE emp (
    empname           text PRIMARY KEY,
    salary            integer
);

CREATE TABLE emp_audit(
    operation         char(1)   NOT NULL,
    userid            text      NOT NULL,
    empname           text      NOT NULL,
    salary            integer,
    stamp             timestamp NOT NULL
);

CREATE VIEW emp_view AS
    SELECT e.empname,
           e.salary,
           max(ea.stamp) AS last_updated
      FROM emp e
      LEFT JOIN emp_audit ea ON ea.empname = e.empname
     GROUP BY 1, 2;

CREATE OR REPLACE FUNCTION update_emp_view() RETURNS TRIGGER AS $$
    BEGIN
        --
        -- Perform the required operation on emp, and create a row in emp_audit
        -- to reflect the change made to emp.
        --
        IF (TG_OP = 'DELETE') THEN
            DELETE FROM emp WHERE empname = OLD.empname;
            IF NOT FOUND THEN RETURN NULL; END IF;

            OLD.last_updated = now();
            INSERT INTO emp_audit VALUES('D', user, OLD.*);
            RETURN OLD;
        ELSIF (TG_OP = 'UPDATE') THEN
            UPDATE emp SET salary = NEW.salary WHERE empname = OLD.empname;
            IF NOT FOUND THEN RETURN NULL; END IF;

            NEW.last_updated = now();
            INSERT INTO emp_audit VALUES('U', user, NEW.*);
            RETURN NEW;
        ELSIF (TG_OP = 'INSERT') THEN
            INSERT INTO emp VALUES(NEW.empname, NEW.salary);

            NEW.last_updated = now();
            INSERT INTO emp_audit VALUES('I', user, NEW.*);
            RETURN NEW;
```

```
        END IF;
    END;
$$ LANGUAGE plpgsql;

CREATE TRIGGER emp_audit
INSTEAD OF INSERT OR UPDATE OR DELETE ON emp_view
    FOR EACH ROW EXECUTE PROCEDURE update_emp_view();
```

One use of triggers is to maintain a summary table of another table. The resulting summary can be used in place of the original table for certain queries — often with vastly reduced run times. This technique is commonly used in Data Warehousing, where the tables of measured or observed data (called fact tables) might be extremely large. Example 40-6 shows an example of a trigger procedure in PL/pgSQL that maintains a summary table for a fact table in a data warehouse.

Example 40-6. A PL/pgSQL Trigger Procedure For Maintaining A Summary Table

The schema detailed here is partly based on the *Grocery Store* example from *The Data Warehouse Toolkit* by Ralph Kimball.

```
--
-- Main tables - time dimension and sales fact.
--
CREATE TABLE time_dimension (
    time_key                    integer NOT NULL,
    day_of_week                 integer NOT NULL,
    day_of_month                integer NOT NULL,
    month                       integer NOT NULL,
    quarter                     integer NOT NULL,
    year                        integer NOT NULL
);
CREATE UNIQUE INDEX time_dimension_key ON time_dimension(time_key);

CREATE TABLE sales_fact (
    time_key                    integer NOT NULL,
    product_key                 integer NOT NULL,
    store_key                   integer NOT NULL,
    amount_sold                 numeric(12,2) NOT NULL,
    units_sold                  integer NOT NULL,
    amount_cost                 numeric(12,2) NOT NULL
);
CREATE INDEX sales_fact_time ON sales_fact(time_key);

--
-- Summary table - sales by time.
--
CREATE TABLE sales_summary_bytime (
    time_key                    integer NOT NULL,
    amount_sold                 numeric(15,2) NOT NULL,
    units_sold                  numeric(12) NOT NULL,
    amount_cost                 numeric(15,2) NOT NULL
);
CREATE UNIQUE INDEX sales_summary_bytime_key ON sales_summary_bytime(time_key);

--
-- Function and trigger to amend summarized column(s) on UPDATE, INSERT, DELETE.
--
CREATE OR REPLACE FUNCTION maint_sales_summary_bytime() RETURNS TRIGGER
```

```
AS $maint_sales_summary_bytime$
    DECLARE
        delta_time_key          integer;
        delta_amount_sold       numeric(15,2);
        delta_units_sold        numeric(12);
        delta_amount_cost       numeric(15,2);
    BEGIN

        -- Work out the increment/decrement amount(s).
        IF (TG_OP = 'DELETE') THEN

            delta_time_key = OLD.time_key;
            delta_amount_sold = -1 * OLD.amount_sold;
            delta_units_sold = -1 * OLD.units_sold;
            delta_amount_cost = -1 * OLD.amount_cost;

        ELSIF (TG_OP = 'UPDATE') THEN

            -- forbid updates that change the time_key -
            -- (probably not too onerous, as DELETE + INSERT is how most
            -- changes will be made).
            IF ( OLD.time_key != NEW.time_key) THEN
                RAISE EXCEPTION 'Update of time_key : % -> % not allowed',
                                                    OLD.time_key, NEW.time_key;
            END IF;

            delta_time_key = OLD.time_key;
            delta_amount_sold = NEW.amount_sold - OLD.amount_sold;
            delta_units_sold = NEW.units_sold - OLD.units_sold;
            delta_amount_cost = NEW.amount_cost - OLD.amount_cost;

        ELSIF (TG_OP = 'INSERT') THEN

            delta_time_key = NEW.time_key;
            delta_amount_sold = NEW.amount_sold;
            delta_units_sold = NEW.units_sold;
            delta_amount_cost = NEW.amount_cost;

        END IF;


        -- Insert or update the summary row with the new values.
        <<insert_update>>
        LOOP
            UPDATE sales_summary_bytime
                SET amount_sold = amount_sold + delta_amount_sold,
                    units_sold = units_sold + delta_units_sold,
                    amount_cost = amount_cost + delta_amount_cost
                WHERE time_key = delta_time_key;

            EXIT insert_update WHEN found;

            BEGIN
                INSERT INTO sales_summary_bytime (
                            time_key,
                            amount_sold,
                            units_sold,
```

```
                        amount_cost)
                    VALUES (
                        delta_time_key,
                        delta_amount_sold,
                        delta_units_sold,
                        delta_amount_cost
                       );

                EXIT insert_update;

            EXCEPTION
                WHEN UNIQUE_VIOLATION THEN
                    -- do nothing
            END;
        END LOOP insert_update;

        RETURN NULL;

    END;
$maint_sales_summary_bytime$ LANGUAGE plpgsql;

CREATE TRIGGER maint_sales_summary_bytime
AFTER INSERT OR UPDATE OR DELETE ON sales_fact
    FOR EACH ROW EXECUTE PROCEDURE maint_sales_summary_bytime();

INSERT INTO sales_fact VALUES(1,1,1,10,3,15);
INSERT INTO sales_fact VALUES(1,2,1,20,5,35);
INSERT INTO sales_fact VALUES(2,2,1,40,15,135);
INSERT INTO sales_fact VALUES(2,3,1,10,1,13);
SELECT * FROM sales_summary_bytime;
DELETE FROM sales_fact WHERE product_key = 1;
SELECT * FROM sales_summary_bytime;
UPDATE sales_fact SET units_sold = units_sold * 2;
SELECT * FROM sales_summary_bytime;
```

40.9.2. Triggers on Events

PL/pgSQL can be used to define event triggers. PostgreSQL requires that a procedure that is to be called as an event trigger must be declared as a function with no arguments and a return type of `event_trigger`.

When a PL/pgSQL function is called as a event trigger, several special variables are created automatically in the top-level block. They are:

`TG_EVENT`

Data type `text`; a string representing the event the trigger is fired for.

`TG_TAG`

Data type `text`; variable that contains the command tag for which the trigger is fired.

Example 40-7 shows an example of a event trigger procedure in PL/pgSQL.

Example 40-7. A PL/pgSQL Event Trigger Procedure

This example trigger simply raises a NOTICE message each time a supported command is executed.

```
CREATE OR REPLACE FUNCTION snitch() RETURNS event_trigger AS $$
BEGIN
    RAISE NOTICE 'snitch: % %', tg_event, tg_tag;
END;
$$ LANGUAGE plpgsql;

CREATE EVENT TRIGGER snitch ON ddl_command_start EXECUTE PROCEDURE snitch();
```

40.10. PL/pgSQL Under the Hood

This section discusses some implementation details that are frequently important for PL/pgSQL users to know.

40.10.1. Variable Substitution

SQL statements and expressions within a PL/pgSQL function can refer to variables and parameters of the function. Behind the scenes, PL/pgSQL substitutes query parameters for such references. Parameters will only be substituted in places where a parameter or column reference is syntactically allowed. As an extreme case, consider this example of poor programming style:

```
INSERT INTO foo (foo) VALUES (foo);
```

The first occurrence of `foo` must syntactically be a table name, so it will not be substituted, even if the function has a variable named `foo`. The second occurrence must be the name of a column of the table, so it will not be substituted either. Only the third occurrence is a candidate to be a reference to the function's variable.

> **Note:** PostgreSQL versions before 9.0 would try to substitute the variable in all three cases, leading to syntax errors.

Since the names of variables are syntactically no different from the names of table columns, there can be ambiguity in statements that also refer to tables: is a given name meant to refer to a table column, or a variable? Let's change the previous example to

```
INSERT INTO dest (col) SELECT foo + bar FROM src;
```

Here, `dest` and `src` must be table names, and `col` must be a column of `dest`, but `foo` and `bar` might reasonably be either variables of the function or columns of `src`.

By default, PL/pgSQL will report an error if a name in a SQL statement could refer to either a variable or a table column. You can fix such a problem by renaming the variable or column, or by qualifying the ambiguous reference, or by telling PL/pgSQL which interpretation to prefer.

The simplest solution is to rename the variable or column. A common coding rule is to use a different naming convention for PL/pgSQL variables than you use for column names. For example, if you consistently name function variables `v_`*`something`* while none of your column names start with `v_`, no conflicts will occur.

Alternatively you can qualify ambiguous references to make them clear. In the above example, `src.foo` would be an unambiguous reference to the table column. To create an unambiguous reference to a variable, declare it in a labeled block and use the block's label (see Section 40.2). For example,

```
<<block>>
DECLARE
    foo int;
BEGIN
    foo := ...;
    INSERT INTO dest (col) SELECT block.foo + bar FROM src;
```

Here `block.foo` means the variable even if there is a column `foo` in `src`. Function parameters, as well as special variables such as `FOUND`, can be qualified by the function's name, because they are implicitly declared in an outer block labeled with the function's name.

Sometimes it is impractical to fix all the ambiguous references in a large body of PL/pgSQL code. In such cases you can specify that PL/pgSQL should resolve ambiguous references as the variable (which is compatible with PL/pgSQL's behavior before PostgreSQL 9.0), or as the table column (which is compatible with some other systems such as Oracle).

To change this behavior on a system-wide basis, set the configuration parameter `plpgsql.variable_conflict` to one of `error`, `use_variable`, or `use_column` (where `error` is the factory default). This parameter affects subsequent compilations of statements in PL/pgSQL functions, but not statements already compiled in the current session. Because changing this setting can cause unexpected changes in the behavior of PL/pgSQL functions, it can only be changed by a superuser.

You can also set the behavior on a function-by-function basis, by inserting one of these special commands at the start of the function text:

```
#variable_conflict error
#variable_conflict use_variable
#variable_conflict use_column
```

These commands affect only the function they are written in, and override the setting of `plpgsql.variable_conflict`. An example is

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    #variable_conflict use_variable
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = curtime, comment = comment
          WHERE users.id = id;
    END;
$$ LANGUAGE plpgsql;
```

In the `UPDATE` command, `curtime`, `comment`, and `id` will refer to the function's variable and parameters whether or not `users` has columns of those names. Notice that we had to qualify the reference to `users.id` in the `WHERE` clause to make it refer to the table column. But we did not have to qualify the reference to `comment` as a target in the `UPDATE` list, because syntactically that must be a column of `users`. We could write the same function without depending on the `variable_conflict` setting in this way:

```
CREATE FUNCTION stamp_user(id int, comment text) RETURNS void AS $$
    <<fn>>
```

```
    DECLARE
        curtime timestamp := now();
    BEGIN
        UPDATE users SET last_modified = fn.curtime, comment = stamp_user.comment
          WHERE users.id = stamp_user.id;
    END;
$$ LANGUAGE plpgsql;
```

Variable substitution does not happen in the command string given to `EXECUTE` or one of its variants. If you need to insert a varying value into such a command, do so as part of constructing the string value, or use `USING`, as illustrated in Section 40.5.4.

Variable substitution currently works only in `SELECT`, `INSERT`, `UPDATE`, and `DELETE` commands, because the main SQL engine allows query parameters only in these commands. To use a non-constant name or value in other statement types (generically called utility statements), you must construct the utility statement as a string and `EXECUTE` it.

40.10.2. Plan Caching

The PL/pgSQL interpreter parses the function's source text and produces an internal binary instruction tree the first time the function is called (within each session). The instruction tree fully translates the PL/pgSQL statement structure, but individual SQL expressions and SQL commands used in the function are not translated immediately.

As each expression and SQL command is first executed in the function, the PL/pgSQL interpreter parses and analyzes the command to create a prepared statement, using the SPI manager's `SPI_prepare` function. Subsequent visits to that expression or command reuse the prepared statement. Thus, a function with conditional code paths that are seldom visited will never incur the overhead of analyzing those commands that are never executed within the current session. A disadvantage is that errors in a specific expression or command cannot be detected until that part of the function is reached in execution. (Trivial syntax errors will be detected during the initial parsing pass, but anything deeper will not be detected until execution.)

PL/pgSQL (or more precisely, the SPI manager) can furthermore attempt to cache the execution plan associated with any particular prepared statement. If a cached plan is not used, then a fresh execution plan is generated on each visit to the statement, and the current parameter values (that is, PL/pgSQL variable values) can be used to optimize the selected plan. If the statement has no parameters, or is executed many times, the SPI manager will consider creating a *generic* plan that is not dependent on specific parameter values, and caching that for re-use. Typically this will happen only if the execution plan is not very sensitive to the values of the PL/pgSQL variables referenced in it. If it is, generating a plan each time is a net win. See PREPARE for more information about the behavior of prepared statements.

Because PL/pgSQL saves prepared statements and sometimes execution plans in this way, SQL commands that appear directly in a PL/pgSQL function must refer to the same tables and columns on every execution; that is, you cannot use a parameter as the name of a table or column in an SQL command. To get around this restriction, you can construct dynamic commands using the PL/pgSQL `EXECUTE` statement — at the price of performing new parse analysis and constructing a new execution plan on every execution.

The mutable nature of record variables presents another problem in this connection. When fields of a record variable are used in expressions or statements, the data types of the fields must not change from one call of the function to the next, since each expression will be analyzed using the data type

that is present when the expression is first reached. EXECUTE can be used to get around this problem when necessary.

If the same function is used as a trigger for more than one table, PL/pgSQL prepares and caches statements independently for each such table — that is, there is a cache for each trigger function and table combination, not just for each function. This alleviates some of the problems with varying data types; for instance, a trigger function will be able to work successfully with a column named key even if it happens to have different types in different tables.

Likewise, functions having polymorphic argument types have a separate statement cache for each combination of actual argument types they have been invoked for, so that data type differences do not cause unexpected failures.

Statement caching can sometimes have surprising effects on the interpretation of time-sensitive values. For example there is a difference between what these two functions do:

```
CREATE FUNCTION logfunc1(logtxt text) RETURNS void AS $$
    BEGIN
        INSERT INTO logtable VALUES (logtxt, 'now');
    END;
$$ LANGUAGE plpgsql;
```

and:

```
CREATE FUNCTION logfunc2(logtxt text) RETURNS void AS $$
    DECLARE
        curtime timestamp;
    BEGIN
        curtime := 'now';
        INSERT INTO logtable VALUES (logtxt, curtime);
    END;
$$ LANGUAGE plpgsql;
```

In the case of logfunc1, the PostgreSQL main parser knows when analyzing the INSERT that the string 'now' should be interpreted as timestamp, because the target column of logtable is of that type. Thus, 'now' will be converted to a timestamp constant when the INSERT is analyzed, and then used in all invocations of logfunc1 during the lifetime of the session. Needless to say, this isn't what the programmer wanted. A better idea is to use the now() or current_timestamp function.

In the case of logfunc2, the PostgreSQL main parser does not know what type 'now' should become and therefore it returns a data value of type text containing the string now. During the ensuing assignment to the local variable curtime, the PL/pgSQL interpreter casts this string to the timestamp type by calling the text_out and timestamp_in functions for the conversion. So, the computed time stamp is updated on each execution as the programmer expects. Even though this happens to work as expected, it's not terribly efficient, so use of the now() function would still be a better idea.

40.11. Tips for Developing in PL/pgSQL

One good way to develop in PL/pgSQL is to use the text editor of your choice to create your functions, and in another window, use psql to load and test those functions. If you are doing it this way, it is a

good idea to write the function using `CREATE OR REPLACE FUNCTION`. That way you can just reload the file to update the function definition. For example:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS $$
          ....
$$ LANGUAGE plpgsql;
```

While running psql, you can load or reload such a function definition file with:

```
\i filename.sql
```

and then immediately issue SQL commands to test the function.

Another good way to develop in PL/pgSQL is with a GUI database access tool that facilitates development in a procedural language. One example of such a tool is pgAdmin, although others exist. These tools often provide convenient features such as escaping single quotes and making it easier to recreate and debug functions.

40.11.1. Handling of Quotation Marks

The code of a PL/pgSQL function is specified in `CREATE FUNCTION` as a string literal. If you write the string literal in the ordinary way with surrounding single quotes, then any single quotes inside the function body must be doubled; likewise any backslashes must be doubled (assuming escape string syntax is used). Doubling quotes is at best tedious, and in more complicated cases the code can become downright incomprehensible, because you can easily find yourself needing half a dozen or more adjacent quote marks. It's recommended that you instead write the function body as a "dollar-quoted" string literal (see Section 4.1.2.4). In the dollar-quoting approach, you never double any quote marks, but instead take care to choose a different dollar-quoting delimiter for each level of nesting you need. For example, you might write the `CREATE FUNCTION` command as:

```
CREATE OR REPLACE FUNCTION testfunc(integer) RETURNS integer AS $PROC$
          ....
$PROC$ LANGUAGE plpgsql;
```

Within this, you might use quote marks for simple literal strings in SQL commands and `$$` to delimit fragments of SQL commands that you are assembling as strings. If you need to quote text that includes `$$`, you could use `$Q$`, and so on.

The following chart shows what you have to do when writing quote marks without dollar quoting. It might be useful when translating pre-dollar quoting code into something more comprehensible.

1 quotation mark

To begin and end the function body, for example:

```
CREATE FUNCTION foo() RETURNS integer AS '
          ....
' LANGUAGE plpgsql;
```

Anywhere within a single-quoted function body, quote marks *must* appear in pairs.

2 quotation marks

For string literals inside the function body, for example:

```
a_output := ”Blah”;
SELECT * FROM users WHERE f_name=”foobar”;
```

In the dollar-quoting approach, you'd just write:

```
a_output := 'Blah';
SELECT * FROM users WHERE f_name='foobar';
```
which is exactly what the PL/pgSQL parser would see in either case.

4 quotation marks

When you need a single quotation mark in a string constant inside the function body, for example:

```
a_output := a_output || '' AND name LIKE ''foobar'' AND xyz''
```
The value actually appended to `a_output` would be: `AND name LIKE 'foobar' AND xyz`.

In the dollar-quoting approach, you'd write:

```
a_output := a_output || $$ AND name LIKE 'foobar' AND xyz$$
```
being careful that any dollar-quote delimiters around this are not just `$$`.

6 quotation marks

When a single quotation mark in a string inside the function body is adjacent to the end of that string constant, for example:

```
a_output := a_output || '' AND name LIKE ''foobar''''
```
The value appended to `a_output` would then be: `AND name LIKE 'foobar'`.

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ AND name LIKE 'foobar'$$
```

10 quotation marks

When you want two single quotation marks in a string constant (which accounts for 8 quotation marks) and this is adjacent to the end of that string constant (2 more). You will probably only need that if you are writing a function that generates other functions, as in Example 40-9. For example:

```
a_output := a_output || '' if v_'' ||
    referrer_keys.kind || '' like ''''''
    || referrer_keys.key_string || ''''''
    then return ''''  || referrer_keys.referrer_type
    || ''''; end if;'';
```
The value of `a_output` would then be:

```
if v_... like ''...'' then return ''...''; end if;
```

In the dollar-quoting approach, this becomes:

```
a_output := a_output || $$ if v_$$ || referrer_keys.kind || $$ like '$$
    || referrer_keys.key_string || $$'
    then return '$$  || referrer_keys.referrer_type
    || $$'; end if;$$;
```
where we assume we only need to put single quote marks into `a_output`, because it will be re-quoted before use.

40.11.2. Additional Compile-time Checks

To aid the user in finding instances of simple but common problems before they cause harm, PL/PgSQL provides additional *checks*. When enabled, depending on the configuration, they can be used to emit either a `WARNING` or an `ERROR` during the compilation of a function. A function which has received a `WARNING` can be executed without producing further messages, so you are advised to test in a separate development environment.

These additional checks are enabled through the configuration variables `plpgsql.extra_warnings` for warnings and `plpgsql.extra_errors` for errors. Both can be set either to a comma-separated

list of checks, "none" or "all". The default is "none". Currently the list of available checks includes only one:

shadowed_variables

Checks if a declaration shadows a previously defined variable.

The following example shows the effect of plpgsql.extra_warnings set to shadowed_variables:

```
SET plpgsql.extra_warnings TO 'shadowed_variables';

CREATE FUNCTION foo(f1 int) RETURNS int AS $$
DECLARE
f1 int;
BEGIN
RETURN f1;
END
$$ LANGUAGE plpgsql;
WARNING:  variable "f1" shadows a previously defined variable
LINE 3: f1 int;
        ^
CREATE FUNCTION
```

40.12. Porting from Oracle PL/SQL

This section explains differences between PostgreSQL's PL/pgSQL language and Oracle's PL/SQL language, to help developers who port applications from Oracle® to PostgreSQL.

PL/pgSQL is similar to PL/SQL in many aspects. It is a block-structured, imperative language, and all variables have to be declared. Assignments, loops, conditionals are similar. The main differences you should keep in mind when porting from PL/SQL to PL/pgSQL are:

- If a name used in a SQL command could be either a column name of a table or a reference to a variable of the function, PL/SQL treats it as a column name. This corresponds to PL/pgSQL's plpgsql.variable_conflict = use_column behavior, which is not the default, as explained in Section 40.10.1. It's often best to avoid such ambiguities in the first place, but if you have to port a large amount of code that depends on this behavior, setting variable_conflict may be the best solution.
- In PostgreSQL the function body must be written as a string literal. Therefore you need to use dollar quoting or escape single quotes in the function body. (See Section 40.11.1.)
- Instead of packages, use schemas to organize your functions into groups.
- Since there are no packages, there are no package-level variables either. This is somewhat annoying. You can keep per-session state in temporary tables instead.
- Integer FOR loops with REVERSE work differently: PL/SQL counts down from the second number to the first, while PL/pgSQL counts down from the first number to the second, requiring the loop bounds to be swapped when porting. This incompatibility is unfortunate but is unlikely to be changed. (See Section 40.6.3.5.)

- `FOR` loops over queries (other than cursors) also work differently: the target variable(s) must have been declared, whereas PL/SQL always declares them implicitly. An advantage of this is that the variable values are still accessible after the loop exits.
- There are various notational differences for the use of cursor variables.

40.12.1. Porting Examples

Example 40-8 shows how to port a simple function from PL/SQL to PL/pgSQL.

Example 40-8. Porting a Simple Function from PL/SQL to PL/pgSQL

Here is an Oracle PL/SQL function:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar,
                                                  v_version varchar)
RETURN varchar IS
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
/
show errors;
```

Let's go through this function and see the differences compared to PL/pgSQL:

- The `RETURN` key word in the function prototype (not the function body) becomes `RETURNS` in PostgreSQL. Also, `IS` becomes `AS`, and you need to add a `LANGUAGE` clause because PL/pgSQL is not the only possible function language.
- In PostgreSQL, the function body is considered to be a string literal, so you need to use quote marks or dollar quotes around it. This substitutes for the terminating `/` in the Oracle approach.
- The `show errors` command does not exist in PostgreSQL, and is not needed since errors are reported automatically.

This is how this function would look when ported to PostgreSQL:

```
CREATE OR REPLACE FUNCTION cs_fmt_browser_version(v_name varchar,
                                                  v_version varchar)
RETURNS varchar AS $$
BEGIN
    IF v_version IS NULL THEN
        RETURN v_name;
    END IF;
    RETURN v_name || '/' || v_version;
END;
$$ LANGUAGE plpgsql;
```

Example 40-9 shows how to port a function that creates another function and how to handle the ensuing quoting problems.

Example 40-9. Porting a Function that Creates Another Function from PL/SQL to PL/pgSQL

The following procedure grabs rows from a `SELECT` statement and builds a large function with the results in `IF` statements, for the sake of efficiency.

This is the Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_update_referrer_type_proc IS
    CURSOR referrer_keys IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_cmd VARCHAR(4000);
BEGIN
    func_cmd := 'CREATE OR REPLACE FUNCTION cs_find_referrer_type(v_host IN VARCHAR,
                 v_domain IN VARCHAR, v_url IN VARCHAR) RETURN VARCHAR IS BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_cmd := func_cmd ||
          ' IF v_' || referrer_key.kind
          || ' LIKE ''' || referrer_key.key_string
          || ''' THEN RETURN ''' || referrer_key.referrer_type
          || '''; END IF;';
    END LOOP;

    func_cmd := func_cmd || ' RETURN NULL; END;';

    EXECUTE IMMEDIATE func_cmd;
END;
/
show errors;
```

Here is how this function would end up in PostgreSQL:

```
CREATE OR REPLACE FUNCTION cs_update_referrer_type_proc() RETURNS void AS $func$
DECLARE
    referrer_keys CURSOR IS
        SELECT * FROM cs_referrer_keys
        ORDER BY try_order;
    func_body text;
    func_cmd text;
BEGIN
    func_body := 'BEGIN';

    FOR referrer_key IN referrer_keys LOOP
        func_body := func_body ||
          ' IF v_' || referrer_key.kind
          || ' LIKE ' || quote_literal(referrer_key.key_string)
          || ' THEN RETURN ' || quote_literal(referrer_key.referrer_type)
          || '; END IF;' ;
    END LOOP;

    func_body := func_body || ' RETURN NULL; END;';

    func_cmd :=
      'CREATE OR REPLACE FUNCTION cs_find_referrer_type(v_host varchar,
                                                        v_domain varchar,
                                                        v_url varchar)
        RETURNS varchar AS '
      || quote_literal(func_body)
```

```
      || ' LANGUAGE plpgsql;' ;

    EXECUTE func_cmd;
END;
$func$ LANGUAGE plpgsql;
```

Notice how the body of the function is built separately and passed through `quote_literal` to double any quote marks in it. This technique is needed because we cannot safely use dollar quoting for defining the new function: we do not know for sure what strings will be interpolated from the `referrer_key.key_string` field. (We are assuming here that `referrer_key.kind` can be trusted to always be `host`, `domain`, or `url`, but `referrer_key.key_string` might be anything, in particular it might contain dollar signs.) This function is actually an improvement on the Oracle original, because it will not generate broken code when `referrer_key.key_string` or `referrer_key.referrer_type` contain quote marks.

Example 40-10 shows how to port a function with `OUT` parameters and string manipulation. PostgreSQL does not have a built-in `instr` function, but you can create one using a combination of other functions. In Section 40.12.3 there is a PL/pgSQL implementation of `instr` that you can use to make your porting easier.

Example 40-10. Porting a Procedure With String Manipulation and `OUT` Parameters from PL/SQL to PL/pgSQL

The following Oracle PL/SQL procedure is used to parse a URL and return several elements (host, path, and query).

This is the Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_parse_url(
    v_url IN VARCHAR,
    v_host OUT VARCHAR,  -- This will be passed back
    v_path OUT VARCHAR,  -- This one too
    v_query OUT VARCHAR) -- And this one
IS
    a_pos1 INTEGER;
    a_pos2 INTEGER;
BEGIN
    v_host := NULL;
    v_path := NULL;
    v_query := NULL;
    a_pos1 := instr(v_url, '//');

    IF a_pos1 = 0 THEN
        RETURN;
    END IF;
    a_pos2 := instr(v_url, '/', a_pos1 + 2);
    IF a_pos2 = 0 THEN
        v_host := substr(v_url, a_pos1 + 2);
        v_path := '/';
        RETURN;
    END IF;

    v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);
    a_pos1 := instr(v_url, '?', a_pos2 + 1);

    IF a_pos1 = 0 THEN
```

```
        v_path := substr(v_url, a_pos2);
        RETURN;
    END IF;

    v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);
    v_query := substr(v_url, a_pos1 + 1);
END;
/
show errors;
```

Here is a possible translation into PL/pgSQL:

```
CREATE OR REPLACE FUNCTION cs_parse_url(
    v_url IN VARCHAR,
    v_host OUT VARCHAR,  -- This will be passed back
    v_path OUT VARCHAR,  -- This one too
    v_query OUT VARCHAR) -- And this one
AS $$
DECLARE
    a_pos1 INTEGER;
    a_pos2 INTEGER;
BEGIN
    v_host := NULL;
    v_path := NULL;
    v_query := NULL;
    a_pos1 := instr(v_url, '//');

    IF a_pos1 = 0 THEN
        RETURN;
    END IF;
    a_pos2 := instr(v_url, '/', a_pos1 + 2);
    IF a_pos2 = 0 THEN
        v_host := substr(v_url, a_pos1 + 2);
        v_path := '/';
        RETURN;
    END IF;

    v_host := substr(v_url, a_pos1 + 2, a_pos2 - a_pos1 - 2);
    a_pos1 := instr(v_url, '?', a_pos2 + 1);

    IF a_pos1 = 0 THEN
        v_path := substr(v_url, a_pos2);
        RETURN;
    END IF;

    v_path := substr(v_url, a_pos2, a_pos1 - a_pos2);
    v_query := substr(v_url, a_pos1 + 1);
END;
$$ LANGUAGE plpgsql;
```

This function could be used like this:

```
SELECT * FROM cs_parse_url('http://foobar.com/query.cgi?baz');
```

Example 40-11 shows how to port a procedure that uses numerous features that are specific to Oracle.

Example 40-11. Porting a Procedure from PL/SQL to PL/pgSQL

The Oracle version:

```
CREATE OR REPLACE PROCEDURE cs_create_job(v_job_id IN INTEGER) IS
    a_running_job_count INTEGER;
    PRAGMA AUTONOMOUS_TRANSACTION;❶
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;❷

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        COMMIT; -- free lock❸
        raise_application_error(-20000,
                'Unable to create a new job: a job is currently running.');
    END IF;

    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id, sysdate);
    EXCEPTION
        WHEN dup_val_on_index THEN NULL; -- don't worry if it already exists
    END;
    COMMIT;
END;
/
show errors
```

Procedures like this can easily be converted into PostgreSQL functions returning `void`. This procedure in particular is interesting because it can teach us some things:

❶ There is no `PRAGMA` statement in PostgreSQL.

❷ If you do a `LOCK TABLE` in PL/pgSQL, the lock will not be released until the calling transaction is finished.

❸ You cannot issue `COMMIT` in a PL/pgSQL function. The function is running within some outer transaction and so `COMMIT` would imply terminating the function's execution. However, in this particular case it is not necessary anyway, because the lock obtained by the `LOCK TABLE` will be released when we raise an error.

This is how we could port this procedure to PL/pgSQL:

```
CREATE OR REPLACE FUNCTION cs_create_job(v_job_id integer) RETURNS void AS $$
DECLARE
    a_running_job_count integer;
BEGIN
    LOCK TABLE cs_jobs IN EXCLUSIVE MODE;

    SELECT count(*) INTO a_running_job_count FROM cs_jobs WHERE end_stamp IS NULL;

    IF a_running_job_count > 0 THEN
        RAISE EXCEPTION 'Unable to create a new job: a job is currently running';❶
    END IF;
```

```
    DELETE FROM cs_active_job;
    INSERT INTO cs_active_job(job_id) VALUES (v_job_id);

    BEGIN
        INSERT INTO cs_jobs (job_id, start_stamp) VALUES (v_job_id, now());
    EXCEPTION
        WHEN unique_violation THEN ❷
            -- don't worry if it already exists
    END;
END;
$$ LANGUAGE plpgsql;
```

❶ The syntax of `RAISE` is considerably different from Oracle's statement, although the basic case `RAISE` *`exception_name`* works similarly.

❷ The exception names supported by PL/pgSQL are different from Oracle's. The set of built-in exception names is much larger (see Appendix A). There is not currently a way to declare user-defined exception names, although you can throw user-chosen SQLSTATE values instead.

The main functional difference between this procedure and the Oracle equivalent is that the exclusive lock on the `cs_jobs` table will be held until the calling transaction completes. Also, if the caller later aborts (for example due to an error), the effects of this procedure will be rolled back.

40.12.2. Other Things to Watch For

This section explains a few other things to watch for when porting Oracle PL/SQL functions to PostgreSQL.

40.12.2.1. Implicit Rollback after Exceptions

In PL/pgSQL, when an exception is caught by an `EXCEPTION` clause, all database changes since the block's `BEGIN` are automatically rolled back. That is, the behavior is equivalent to what you'd get in Oracle with:

```
BEGIN
    SAVEPOINT s1;
    ... code here ...
EXCEPTION
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
    WHEN ... THEN
        ROLLBACK TO s1;
        ... code here ...
END;
```

If you are translating an Oracle procedure that uses `SAVEPOINT` and `ROLLBACK TO` in this style, your task is easy: just omit the `SAVEPOINT` and `ROLLBACK TO`. If you have a procedure that uses `SAVEPOINT` and `ROLLBACK TO` in a different way then some actual thought will be required.

40.12.2.2. EXECUTE

The PL/pgSQL version of EXECUTE works similarly to the PL/SQL version, but you have to remember to use quote_literal and quote_ident as described in Section 40.5.4. Constructs of the type EXECUTE 'SELECT * FROM $1'; will not work reliably unless you use these functions.

40.12.2.3. Optimizing PL/pgSQL Functions

PostgreSQL gives you two function creation modifiers to optimize execution: "volatility" (whether the function always returns the same result when given the same arguments) and "strictness" (whether the function returns null if any argument is null). Consult the CREATE FUNCTION reference page for details.

When making use of these optimization attributes, your CREATE FUNCTION statement might look something like this:

```
CREATE FUNCTION foo(...) RETURNS integer AS $$
...
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

40.12.3. Appendix

This section contains the code for a set of Oracle-compatible instr functions that you can use to simplify your porting efforts.

```
--
-- instr functions that mimic Oracle's counterpart
-- Syntax: instr(string1, string2, [n], [m]) where [] denotes optional parameters.
--
-- Searches string1 beginning at the nth character for the mth occurrence
-- of string2.  If n is negative, search backwards.  If m is not passed,
-- assume 1 (search starts at first character).
--

CREATE FUNCTION instr(varchar, varchar) RETURNS integer AS $$
DECLARE
    pos integer;
BEGIN
    pos:= instr($1, $2, 1);
    RETURN pos;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;


CREATE FUNCTION instr(string varchar, string_to_search varchar, beg_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    length integer;
    ss_length integer;
```

```
BEGIN
    IF beg_index > 0 THEN
        temp_str := substring(string FROM beg_index);
        pos := position(string_to_search IN temp_str);

        IF pos = 0 THEN
            RETURN 0;
        ELSE
            RETURN pos + beg_index - 1;
        END IF;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search);
        length := char_length(string);
        beg := length + beg_index - ss_length + 2;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            pos := position(string_to_search IN temp_str);

            IF pos > 0 THEN
                RETURN beg;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;


CREATE FUNCTION instr(string varchar, string_to_search varchar,
                      beg_index integer, occur_index integer)
RETURNS integer AS $$
DECLARE
    pos integer NOT NULL DEFAULT 0;
    occur_number integer NOT NULL DEFAULT 0;
    temp_str varchar;
    beg integer;
    i integer;
    length integer;
    ss_length integer;
BEGIN
    IF beg_index > 0 THEN
        beg := beg_index;
        temp_str := substring(string FROM beg_index);

        FOR i IN 1..occur_index LOOP
            pos := position(string_to_search IN temp_str);

            IF i = 1 THEN
                beg := beg + pos - 1;
            ELSE
                beg := beg + pos;
```

```
            END IF;

            temp_str := substring(string FROM beg + 1);
        END LOOP;

        IF pos = 0 THEN
            RETURN 0;
        ELSE
            RETURN beg;
        END IF;
    ELSIF beg_index < 0 THEN
        ss_length := char_length(string_to_search);
        length := char_length(string);
        beg := length + beg_index - ss_length + 2;

        WHILE beg > 0 LOOP
            temp_str := substring(string FROM beg FOR ss_length);
            pos := position(string_to_search IN temp_str);

            IF pos > 0 THEN
                occur_number := occur_number + 1;

                IF occur_number = occur_index THEN
                    RETURN beg;
                END IF;
            END IF;

            beg := beg - 1;
        END LOOP;

        RETURN 0;
    ELSE
        RETURN 0;
    END IF;
END;
$$ LANGUAGE plpgsql STRICT IMMUTABLE;
```

Chapter 41. PL/Tcl - Tcl Procedural Language

PL/Tcl is a loadable procedural language for the PostgreSQL database system that enables the Tcl language[1] to be used to write functions and trigger procedures.

41.1. Overview

PL/Tcl offers most of the capabilities a function writer has in the C language, with a few restrictions, and with the addition of the powerful string processing libraries that are available for Tcl.

One compelling *good* restriction is that everything is executed from within the safety of the context of a Tcl interpreter. In addition to the limited command set of safe Tcl, only a few commands are available to access the database via SPI and to raise messages via `elog()`. PL/Tcl provides no way to access internals of the database server or to gain OS-level access under the permissions of the PostgreSQL server process, as a C function can do. Thus, unprivileged database users can be trusted to use this language; it does not give them unlimited authority.

The other notable implementation restriction is that Tcl functions cannot be used to create input/output functions for new data types.

Sometimes it is desirable to write Tcl functions that are not restricted to safe Tcl. For example, one might want a Tcl function that sends email. To handle these cases, there is a variant of PL/Tcl called `PL/TclU` (for untrusted Tcl). This is exactly the same language except that a full Tcl interpreter is used. *If PL/TclU is used, it must be installed as an untrusted procedural language* so that only database superusers can create functions in it. The writer of a PL/TclU function must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator.

The shared object code for the PL/Tcl and PL/TclU call handlers is automatically built and installed in the PostgreSQL library directory if Tcl support is specified in the configuration step of the installation procedure. To install PL/Tcl and/or PL/TclU in a particular database, use the `CREATE EXTENSION` command or the `createlang` program, for example `createlang pltcl` *`dbname`* or `createlang pltclu` *`dbname`*.

41.2. PL/Tcl Functions and Arguments

To create a function in the PL/Tcl language, use the standard CREATE FUNCTION syntax:

```
CREATE FUNCTION funcname (argument-types) RETURNS return-type AS $$
    # PL/Tcl function body
$$ LANGUAGE pltcl;
```

PL/TclU is the same, except that the language has to be specified as `pltclu`.

The body of the function is simply a piece of Tcl script. When the function is called, the argument values are passed as variables `$1` ... `$n` to the Tcl script. The result is returned from the Tcl code in the usual way, with a `return` statement.

For example, a function returning the greater of two integer values could be defined as:

```
CREATE FUNCTION tcl_max(integer, integer) RETURNS integer AS $$
    if {$1 > $2} {return $1}
```

1. http://www.tcl.tk/

```
    return $2
$$ LANGUAGE pltcl STRICT;
```

Note the clause `STRICT`, which saves us from having to think about null input values: if a null value is passed, the function will not be called at all, but will just return a null result automatically.

In a nonstrict function, if the actual value of an argument is null, the corresponding `$n` variable will be set to an empty string. To detect whether a particular argument is null, use the function `argisnull`. For example, suppose that we wanted `tcl_max` with one null and one nonnull argument to return the nonnull argument, rather than null:

```
CREATE FUNCTION tcl_max(integer, integer) RETURNS integer AS $$
    if {[argisnull 1]} {
        if {[argisnull 2]} { return_null }
        return $2
    }
    if {[argisnull 2]} { return $1 }
    if {$1 > $2} {return $1}
    return $2
$$ LANGUAGE pltcl;
```

As shown above, to return a null value from a PL/Tcl function, execute `return_null`. This can be done whether the function is strict or not.

Composite-type arguments are passed to the function as Tcl arrays. The element names of the array are the attribute names of the composite type. If an attribute in the passed row has the null value, it will not appear in the array. Here is an example:

```
CREATE TABLE employee (
    name text,
    salary integer,
    age integer
);

CREATE FUNCTION overpaid(employee) RETURNS boolean AS $$
    if {200000.0 < $1(salary)} {
        return "t"
    }
    if {$1(age) < 30 && 100000.0 < $1(salary)} {
        return "t"
    }
    return "f"
$$ LANGUAGE pltcl;
```

There is currently no support for returning a composite-type result value, nor for returning sets.

PL/Tcl does not currently have full support for domain types: it treats a domain the same as the underlying scalar type. This means that constraints associated with the domain will not be enforced. This is not an issue for function arguments, but it is a hazard if you declare a PL/Tcl function as returning a domain type.

41.3. Data Values in PL/Tcl

The argument values supplied to a PL/Tcl function's code are simply the input arguments converted to text form (just as if they had been displayed by a `SELECT` statement). Conversely, the `return` command will accept any string that is acceptable input format for the function's declared return type. So, within the PL/Tcl function, all values are just text strings.

41.4. Global Data in PL/Tcl

Sometimes it is useful to have some global data that is held between two calls to a function or is shared between different functions. This is easily done in PL/Tcl, but there are some restrictions that must be understood.

For security reasons, PL/Tcl executes functions called by any one SQL role in a separate Tcl interpreter for that role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Tcl functions. Each such interpreter will have its own values for any "global" Tcl variables. Thus, two PL/Tcl functions will share the same global variables if and only if they are executed by the same SQL role. In an application wherein a single session executes code under multiple SQL roles (via `SECURITY DEFINER` functions, use of `SET ROLE`, etc) you may need to take explicit steps to ensure that PL/Tcl functions can share data. To do that, make sure that functions that should communicate are owned by the same user, and mark them `SECURITY DEFINER`. You must of course take care that such functions can't be used to do anything unintended.

All PL/TclU functions used in a session execute in the same Tcl interpreter, which of course is distinct from the interpreter(s) used for PL/Tcl functions. So global data is automatically shared between PL/TclU functions. This is not considered a security risk because all PL/TclU functions execute at the same trust level, namely that of a database superuser.

To help protect PL/Tcl functions from unintentionally interfering with each other, a global array is made available to each function via the `upvar` command. The global name of this variable is the function's internal name, and the local name is `GD`. It is recommended that `GD` be used for persistent private data of a function. Use regular Tcl global variables only for values that you specifically intend to be shared among multiple functions. (Note that the `GD` arrays are only global within a particular interpreter, so they do not bypass the security restrictions mentioned above.)

An example of using `GD` appears in the `spi_execp` example below.

41.5. Database Access from PL/Tcl

The following commands are available to access the database from the body of a PL/Tcl function:

`spi_exec ?-count` *n*`? ?-array` *name*`?` *command* `?`*loop-body*`?`

Executes an SQL command given as a string. An error in the command causes an error to be raised. Otherwise, the return value of `spi_exec` is the number of rows processed (selected, inserted, updated, or deleted) by the command, or zero if the command is a utility statement. In addition, if the command is a `SELECT` statement, the values of the selected columns are placed in Tcl variables as described below.

The optional `-count` value tells `spi_exec` the maximum number of rows to process in the command. The effect of this is comparable to setting up a query as a cursor and then saying `FETCH` *n*.

If the command is a SELECT statement, the values of the result columns are placed into Tcl variables named after the columns. If the -array option is given, the column values are instead stored into the named associative array, with the column names used as array indexes.

If the command is a SELECT statement and no *loop-body* script is given, then only the first row of results are stored into Tcl variables; remaining rows, if any, are ignored. No storing occurs if the query returns no rows. (This case can be detected by checking the result of spi_exec.) For example:

```
spi_exec "SELECT count(*) AS cnt FROM pg_proc"
```

will set the Tcl variable $cnt to the number of rows in the pg_proc system catalog.

If the optional *loop-body* argument is given, it is a piece of Tcl script that is executed once for each row in the query result. (*loop-body* is ignored if the given command is not a SELECT.) The values of the current row's columns are stored into Tcl variables before each iteration. For example:

```
spi_exec -array C "SELECT * FROM pg_class" {
    elog DEBUG "have table $C(relname)"
}
```

will print a log message for every row of pg_class. This feature works similarly to other Tcl looping constructs; in particular continue and break work in the usual way inside the loop body.

If a column of a query result is null, the target variable for it is "unset" rather than being set.

spi_prepare *query typelist*

Prepares and saves a query plan for later execution. The saved plan will be retained for the life of the current session.

The query can use parameters, that is, placeholders for values to be supplied whenever the plan is actually executed. In the query string, refer to parameters by the symbols $1 ... $*n*. If the query uses parameters, the names of the parameter types must be given as a Tcl list. (Write an empty list for *typelist* if no parameters are used.)

The return value from spi_prepare is a query ID to be used in subsequent calls to spi_execp. See spi_execp for an example.

spi_execp ?-count *n*? ?-array *name*? ?-nulls *string*? *queryid* ?*value-list*? ?*loop-body*?

Executes a query previously prepared with spi_prepare. *queryid* is the ID returned by spi_prepare. If the query references parameters, a *value-list* must be supplied. This is a Tcl list of actual values for the parameters. The list must be the same length as the parameter type list previously given to spi_prepare. Omit *value-list* if the query has no parameters.

The optional value for -nulls is a string of spaces and 'n' characters telling spi_execp which of the parameters are null values. If given, it must have exactly the same length as the *value-list*. If it is not given, all the parameter values are nonnull.

Except for the way in which the query and its parameters are specified, spi_execp works just like spi_exec. The -count, -array, and *loop-body* options are the same, and so is the result value.

Here's an example of a PL/Tcl function using a prepared plan:

```
CREATE FUNCTION t1_count(integer, integer) RETURNS integer AS $$
    if {![ info exists GD(plan) ]} {
        # prepare the saved plan on the first call
        set GD(plan) [ spi_prepare \
                "SELECT count(*) AS cnt FROM t1 WHERE num >= \$1 AND num <= \$2" \
```

```
                    [ list int4 int4 ] ]
        }
        spi_execp -count 1 $GD(plan) [ list $1 $2 ]
        return $cnt
    $$ LANGUAGE pltcl;
```

We need backslashes inside the query string given to `spi_prepare` to ensure that the `$n` markers will be passed through to `spi_prepare` as-is, and not replaced by Tcl variable substitution.

`spi_lastoid`

Returns the OID of the row inserted by the last `spi_exec` or `spi_execp`, if the command was a single-row `INSERT` and the modified table contained OIDs. (If not, you get zero.)

`quote` *`string`*

Doubles all occurrences of single quote and backslash characters in the given string. This can be used to safely quote strings that are to be inserted into SQL commands given to `spi_exec` or `spi_prepare`. For example, think about an SQL command string like:

```
"SELECT '$val' AS ret"
```

where the Tcl variable `val` actually contains `doesn't`. This would result in the final command string:

```
SELECT 'doesn't' AS ret
```

which would cause a parse error during `spi_exec` or `spi_prepare`. To work properly, the submitted command should contain:

```
SELECT 'doesn''t' AS ret
```

which can be formed in PL/Tcl using:

```
"SELECT '[ quote $val ]' AS ret"
```

One advantage of `spi_execp` is that you don't have to quote parameter values like this, since the parameters are never parsed as part of an SQL command string.

`elog` *`level msg`*

Emits a log or error message. Possible levels are `DEBUG`, `LOG`, `INFO`, `NOTICE`, `WARNING`, `ERROR`, and `FATAL`. `ERROR` raises an error condition; if this is not trapped by the surrounding Tcl code, the error propagates out to the calling query, causing the current transaction or subtransaction to be aborted. This is effectively the same as the Tcl `error` command. `FATAL` aborts the transaction and causes the current session to shut down. (There is probably no good reason to use this error level in PL/Tcl functions, but it's provided for completeness.) The other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log_min_messages and client_min_messages configuration variables. See Chapter 18 for more information.

41.6. Trigger Procedures in PL/Tcl

Trigger procedures can be written in PL/Tcl. PostgreSQL requires that a procedure that is to be called as a trigger must be declared as a function with no arguments and a return type of `trigger`.

The information from the trigger manager is passed to the procedure body in the following variables:

`$TG_name`

The name of the trigger from the `CREATE TRIGGER` statement.

`$TG_relid`

The object ID of the table that caused the trigger procedure to be invoked.

`$TG_table_name`

The name of the table that caused the trigger procedure to be invoked.

`$TG_table_schema`

The schema of the table that caused the trigger procedure to be invoked.

`$TG_relatts`

A Tcl list of the table column names, prefixed with an empty list element. So looking up a column name in the list with Tcl's `lsearch` command returns the element's number starting with 1 for the first column, the same way the columns are customarily numbered in PostgreSQL. (Empty list elements also appear in the positions of columns that have been dropped, so that the attribute numbering is correct for columns to their right.)

`$TG_when`

The string `BEFORE`, `AFTER`, or `INSTEAD OF`, depending on the type of trigger event.

`$TG_level`

The string `ROW` or `STATEMENT` depending on the type of trigger event.

`$TG_op`

The string `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE` depending on the type of trigger event.

`$NEW`

An associative array containing the values of the new table row for `INSERT` or `UPDATE` actions, or empty for `DELETE`. The array is indexed by column name. Columns that are null will not appear in the array. This is not set for statement-level triggers.

`$OLD`

An associative array containing the values of the old table row for `UPDATE` or `DELETE` actions, or empty for `INSERT`. The array is indexed by column name. Columns that are null will not appear in the array. This is not set for statement-level triggers.

`$args`

A Tcl list of the arguments to the procedure as given in the `CREATE TRIGGER` statement. These arguments are also accessible as `$1` ... `$n` in the procedure body.

The return value from a trigger procedure can be one of the strings `OK` or `SKIP`, or a list as returned by the `array get` Tcl command. If the return value is `OK`, the operation (`INSERT`/`UPDATE`/`DELETE`) that fired the trigger will proceed normally. `SKIP` tells the trigger manager to silently suppress the operation for this row. If a list is returned, it tells PL/Tcl to return a modified row to the trigger manager. This is only meaningful for row-level `BEFORE INSERT` or `UPDATE` triggers for which the modified row will be inserted instead of the one given in `$NEW`; or for row-level `INSTEAD OF INSERT` or `UPDATE` triggers where the returned row is used to support `INSERT RETURNING` and `UPDATE RETURNING` commands. The return value is ignored for other types of triggers.

Here's a little example trigger procedure that forces an integer value in a table to keep track of the number of updates that are performed on the row. For new rows inserted, the value is initialized to 0 and then incremented on every update operation.

```
CREATE FUNCTION trigfunc_modcount() RETURNS trigger AS $$
    switch $TG_op {
```

```
        INSERT {
            set NEW($1) 0
        }
        UPDATE {
            set NEW($1) $OLD($1)
            incr NEW($1)
        }
        default {
            return OK
        }
    }
    return [array get NEW]
$$ LANGUAGE pltcl;

CREATE TABLE mytab (num integer, description text, modcnt integer);

CREATE TRIGGER trig_mytab_modcount BEFORE INSERT OR UPDATE ON mytab
    FOR EACH ROW EXECUTE PROCEDURE trigfunc_modcount('modcnt');
```

Notice that the trigger procedure itself does not know the column name; that's supplied from the trigger arguments. This lets the trigger procedure be reused with different tables.

41.7. Event Trigger Procedures in PL/Tcl

Event trigger procedures can be written in PL/Tcl. PostgreSQL requires that a procedure that is to be called as an event trigger must be declared as a function with no arguments and a return type of `event_trigger`.

The information from the trigger manager is passed to the procedure body in the following variables:

`$TG_event`

The name of the event the trigger is fired for.

`$TG_tag`

The command tag for which the trigger is fired.

The return value of the trigger procedure is ignored.

Here's a little example event trigger procedure that simply raises a `NOTICE` message each time a supported command is executed:

```
CREATE OR REPLACE FUNCTION tclsnitch() RETURNS event_trigger AS $$
  elog NOTICE "tclsnitch: $TG_event $TG_tag"
$$ LANGUAGE pltcl;

CREATE EVENT TRIGGER tcl_a_snitch ON ddl_command_start EXECUTE PROCEDURE tclsnitch();
```

41.8. Modules and the `unknown` Command

PL/Tcl has support for autoloading Tcl code when used. It recognizes a special table, `pltcl_modules`, which is presumed to contain modules of Tcl code. If this table exists, the module `unknown` is fetched from the table and loaded into the Tcl interpreter immediately before the first execution of a PL/Tcl function in a database session. (This happens separately for each Tcl interpreter, if more than one is used in a session; see Section 41.4.)

While the `unknown` module could actually contain any initialization script you need, it normally defines a Tcl `unknown` procedure that is invoked whenever Tcl does not recognize an invoked procedure name. PL/Tcl's standard version of this procedure tries to find a module in `pltcl_modules` that will define the required procedure. If one is found, it is loaded into the interpreter, and then execution is allowed to proceed with the originally attempted procedure call. A secondary table `pltcl_modfuncs` provides an index of which functions are defined by which modules, so that the lookup is reasonably quick.

The PostgreSQL distribution includes support scripts to maintain these tables: `pltcl_loadmod`, `pltcl_listmod`, `pltcl_delmod`, as well as source for the standard `unknown` module in `share/unknown.pltcl`. This module must be loaded into each database initially to support the autoloading mechanism.

The tables `pltcl_modules` and `pltcl_modfuncs` must be readable by all, but it is wise to make them owned and writable only by the database administrator. As a security precaution, PL/Tcl will ignore `pltcl_modules` (and thus, not attempt to load the `unknown` module) unless it is owned by a superuser. But update privileges on this table can be granted to other users, if you trust them sufficiently.

41.9. Tcl Procedure Names

In PostgreSQL, the same function name can be used for different function definitions as long as the number of arguments or their types differ. Tcl, however, requires all procedure names to be distinct. PL/Tcl deals with this by making the internal Tcl procedure names contain the object ID of the function from the system table `pg_proc` as part of their name. Thus, PostgreSQL functions with the same name and different argument types will be different Tcl procedures, too. This is not normally a concern for a PL/Tcl programmer, but it might be visible when debugging.

Chapter 42. PL/Perl - Perl Procedural Language

PL/Perl is a loadable procedural language that enables you to write PostgreSQL functions in the Perl programming language[1].

The main advantage to using PL/Perl is that this allows use, within stored functions, of the manyfold "string munging" operators and functions available for Perl. Parsing complex strings might be easier using Perl than it is with the string functions and control structures provided in PL/pgSQL.

To install PL/Perl in a particular database, use `CREATE EXTENSION plperl`, or from the shell command line use `createlang plperl` *`dbname`*.

> **Tip:** If a language is installed into `template1`, all subsequently created databases will have the language installed automatically.

> **Note:** Users of source packages must specially enable the build of PL/Perl during the installation process. (Refer to Chapter 15 for more information.) Users of binary packages might find PL/Perl in a separate subpackage.

42.1. PL/Perl Functions and Arguments

To create a function in the PL/Perl language, use the standard CREATE FUNCTION syntax:

```
CREATE FUNCTION funcname (argument-types) RETURNS return-type AS $$
    # PL/Perl function body
$$ LANGUAGE plperl;
```

The body of the function is ordinary Perl code. In fact, the PL/Perl glue code wraps it inside a Perl subroutine. A PL/Perl function is called in a scalar context, so it can't return a list. You can return non-scalar values (arrays, records, and sets) by returning a reference, as discussed below.

PL/Perl also supports anonymous code blocks called with the DO statement:

```
DO $$
    # PL/Perl code
$$ LANGUAGE plperl;
```

An anonymous code block receives no arguments, and whatever value it might return is discarded. Otherwise it behaves just like a function.

> **Note:** The use of named nested subroutines is dangerous in Perl, especially if they refer to lexical variables in the enclosing scope. Because a PL/Perl function is wrapped in a subroutine, any named subroutine you place inside one will be nested. In general, it is far safer to create anonymous subroutines which you call via a coderef. For more information, see the entries for `Variable "%s" will not stay shared` and `Variable "%s" is not available` in the perldiag man page, or search the Internet for "perl nested named subroutine".

1. http://www.perl.org

The syntax of the `CREATE FUNCTION` command requires the function body to be written as a string constant. It is usually most convenient to use dollar quoting (see Section 4.1.2.4) for the string constant. If you choose to use escape string syntax `E''`, you must double any single quote marks (`'`) and backslashes (`\`) used in the body of the function (see Section 4.1.2.1).

Arguments and results are handled as in any other Perl subroutine: arguments are passed in `@_`, and a result value is returned with `return` or as the last expression evaluated in the function.

For example, a function returning the greater of two integer values could be defined as:

```
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
    if ($_[0] > $_[1]) { return $_[0]; }
    return $_[1];
$$ LANGUAGE plperl;
```

> **Note:** Arguments will be converted from the database's encoding to UTF-8 for use inside PL/Perl, and then converted from UTF-8 back to the database encoding upon return.

If an SQL null value is passed to a function, the argument value will appear as "undefined" in Perl. The above function definition will not behave very nicely with null inputs (in fact, it will act as though they are zeroes). We could add `STRICT` to the function definition to make PostgreSQL do something more reasonable: if a null value is passed, the function will not be called at all, but will just return a null result automatically. Alternatively, we could check for undefined inputs in the function body. For example, suppose that we wanted `perl_max` with one null and one nonnull argument to return the nonnull argument, rather than a null value:

```
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
    my ($x, $y) = @_;
    if (not defined $x) {
        return undef if not defined $y;
        return $y;
    }
    return $x if not defined $y;
    return $x if $x > $y;
    return $y;
$$ LANGUAGE plperl;
```

As shown above, to return an SQL null value from a PL/Perl function, return an undefined value. This can be done whether the function is strict or not.

Anything in a function argument that is not a reference is a string, which is in the standard PostgreSQL external text representation for the relevant data type. In the case of ordinary numeric or text types, Perl will just do the right thing and the programmer will normally not have to worry about it. However, in other cases the argument will need to be converted into a form that is more usable in Perl. For example, the `decode_bytea` function can be used to convert an argument of type `bytea` into unescaped binary.

Similarly, values passed back to PostgreSQL must be in the external text representation format. For example, the `encode_bytea` function can be used to escape binary data for a return value of type `bytea`.

Perl can return PostgreSQL arrays as references to Perl arrays. Here is an example:

```
CREATE OR REPLACE function returns_array()
```

```
RETURNS text[][] AS $$
    return [['a"b','c,d'],['e\\f','g']];
$$ LANGUAGE plperl;

select returns_array();
```

Perl passes PostgreSQL arrays as a blessed `PostgreSQL::InServer::ARRAY` object. This object may be treated as an array reference or a string, allowing for backward compatibility with Perl code written for PostgreSQL versions below 9.1 to run. For example:

```
CREATE OR REPLACE FUNCTION concat_array_elements(text[]) RETURNS TEXT AS $$
    my $arg = shift;
    my $result = "";
    return undef if (!defined $arg);

    # as an array reference
    for (@$arg) {
        $result .= $_;
    }

    # also works as a string
    $result .= $arg;

    return $result;
$$ LANGUAGE plperl;

SELECT concat_array_elements(ARRAY['PL','/','Perl']);
```

> **Note:** Multidimensional arrays are represented as references to lower-dimensional arrays of references in a way common to every Perl programmer.

Composite-type arguments are passed to the function as references to hashes. The keys of the hash are the attribute names of the composite type. Here is an example:

```
CREATE TABLE employee (
    name text,
    basesalary integer,
    bonus integer
);

CREATE FUNCTION empcomp(employee) RETURNS integer AS $$
    my ($emp) = @_;
    return $emp->{basesalary} + $emp->{bonus};
$$ LANGUAGE plperl;

SELECT name, empcomp(employee.*) FROM employee;
```

A PL/Perl function can return a composite-type result using the same approach: return a reference to a hash that has the required attributes. For example:

```
CREATE TYPE testrowperl AS (f1 integer, f2 text, f3 text);

CREATE OR REPLACE FUNCTION perl_row() RETURNS testrowperl AS $$
    return {f2 => 'hello', f1 => 1, f3 => 'world'};
$$ LANGUAGE plperl;

SELECT * FROM perl_row();
```

Any columns in the declared result data type that are not present in the hash will be returned as null values.

PL/Perl functions can also return sets of either scalar or composite types. Usually you'll want to return rows one at a time, both to speed up startup time and to keep from queuing up the entire result set in memory. You can do this with `return_next` as illustrated below. Note that after the last `return_next`, you must put either `return` or (better) `return undef`.

```
CREATE OR REPLACE FUNCTION perl_set_int(int)
RETURNS SETOF INTEGER AS $$
    foreach (0..$_[0]) {
        return_next($_);
    }
    return undef;
$$ LANGUAGE plperl;

SELECT * FROM perl_set_int(5);

CREATE OR REPLACE FUNCTION perl_set()
RETURNS SETOF testrowperl AS $$
    return_next({ f1 => 1, f2 => 'Hello', f3 => 'World' });
    return_next({ f1 => 2, f2 => 'Hello', f3 => 'PostgreSQL' });
    return_next({ f1 => 3, f2 => 'Hello', f3 => 'PL/Perl' });
    return undef;
$$ LANGUAGE plperl;
```

For small result sets, you can return a reference to an array that contains either scalars, references to arrays, or references to hashes for simple types, array types, and composite types, respectively. Here are some simple examples of returning the entire result set as an array reference:

```
CREATE OR REPLACE FUNCTION perl_set_int(int) RETURNS SETOF INTEGER AS $$
    return [0..$_[0]];
$$ LANGUAGE plperl;

SELECT * FROM perl_set_int(5);

CREATE OR REPLACE FUNCTION perl_set() RETURNS SETOF testrowperl AS $$
    return [
        { f1 => 1, f2 => 'Hello', f3 => 'World' },
        { f1 => 2, f2 => 'Hello', f3 => 'PostgreSQL' },
        { f1 => 3, f2 => 'Hello', f3 => 'PL/Perl' }
    ];
$$ LANGUAGE plperl;

SELECT * FROM perl_set();
```

If you wish to use the `strict` pragma with your code you have a few options. For temporary global use you can `SET plperl.use_strict` to true. This will affect subsequent compilations of PL/Perl

functions, but not functions already compiled in the current session. For permanent global use you can set `plperl.use_strict` to true in the `postgresql.conf` file.

For permanent use in specific functions you can simply put:

```
use strict;
```

at the top of the function body.

The `feature` pragma is also available to `use` if your Perl is version 5.10.0 or higher.

42.2. Data Values in PL/Perl

The argument values supplied to a PL/Perl function's code are simply the input arguments converted to text form (just as if they had been displayed by a `SELECT` statement). Conversely, the `return` and `return_next` commands will accept any string that is acceptable input format for the function's declared return type.

42.3. Built-in Functions

42.3.1. Database Access from PL/Perl

Access to the database itself from your Perl function can be done via the following functions:

`spi_exec_query(`*query* `[, `*max-rows*`])`

`spi_exec_query` executes an SQL command and returns the entire row set as a reference to an array of hash references. *You should only use this command when you know that the result set will be relatively small.* Here is an example of a query (`SELECT` command) with the optional maximum number of rows:

```
$rv = spi_exec_query('SELECT * FROM my_table', 5);
```

This returns up to 5 rows from the table `my_table`. If `my_table` has a column `my_column`, you can get that value from row `$i` of the result like this:

```
$foo = $rv->{rows}[$i]->{my_column};
```

The total number of rows returned from a `SELECT` query can be accessed like this:

```
$nrows = $rv->{processed}
```

Here is an example using a different command type:

```
$query = "INSERT INTO my_table VALUES (1, 'test')";
$rv = spi_exec_query($query);
```

You can then access the command status (e.g., `SPI_OK_INSERT`) like this:

```
$res = $rv->{status};
```

To get the number of rows affected, do:

```
$nrows = $rv->{processed};
```

Here is a complete example:

```
CREATE TABLE test (
    i int,
    v varchar
);
```

```
INSERT INTO test (i, v) VALUES (1, 'first line');
INSERT INTO test (i, v) VALUES (2, 'second line');
INSERT INTO test (i, v) VALUES (3, 'third line');
INSERT INTO test (i, v) VALUES (4, 'immortal');

CREATE OR REPLACE FUNCTION test_munge() RETURNS SETOF test AS $$
    my $rv = spi_exec_query('select i, v from test;');
    my $status = $rv->{status};
    my $nrows = $rv->{processed};
    foreach my $rn (0 .. $nrows - 1) {
        my $row = $rv->{rows}[$rn];
        $row->{i} += 200 if defined($row->{i});
        $row->{v} =~ tr/A-Za-z/a-zA-Z/ if (defined($row->{v}));
        return_next($row);
    }
    return undef;
$$ LANGUAGE plperl;

SELECT * FROM test_munge();
```

`spi_query(`*command*`)`
`spi_fetchrow(`*cursor*`)`
`spi_cursor_close(`*cursor*`)`

`spi_query` and `spi_fetchrow` work together as a pair for row sets which might be large, or for cases where you wish to return rows as they arrive. `spi_fetchrow` works *only* with `spi_query`. The following example illustrates how you use them together:

```
CREATE TYPE foo_type AS (the_num INTEGER, the_text TEXT);

CREATE OR REPLACE FUNCTION lotsa_md5 (INTEGER) RETURNS SETOF foo_type AS $$
    use Digest::MD5 qw(md5_hex);
    my $file = '/usr/share/dict/words';
    my $t = localtime;
    elog(NOTICE, "opening file $file at $t" );
    open my $fh, '<', $file # ooh, it's a file access!
        or elog(ERROR, "cannot open $file for reading: $!");
    my @words = <$fh>;
    close $fh;
    $t = localtime;
    elog(NOTICE, "closed file $file at $t");
    chomp(@words);
    my $row;
    my $sth = spi_query("SELECT * FROM generate_series(1,$_[0]) AS b(a)");
    while (defined ($row = spi_fetchrow($sth))) {
        return_next({
            the_num => $row->{a},
            the_text => md5_hex($words[rand @words])
        });
    }
    return;
$$ LANGUAGE plperlu;

SELECT * from lotsa_md5(500);
```

Normally, `spi_fetchrow` should be repeated until it returns `undef`, indicating that there are no more rows to read. The cursor returned by `spi_query` is automatically freed

when spi_fetchrow returns undef. If you do not wish to read all the rows, instead call spi_cursor_close to free the cursor. Failure to do so will result in memory leaks.

spi_prepare(*command*, *argument types*)
spi_query_prepared(*plan*, *arguments*)
spi_exec_prepared(*plan* [, *attributes*], *arguments*)
spi_freeplan(*plan*)

spi_prepare, spi_query_prepared, spi_exec_prepared, and spi_freeplan implement the same functionality but for prepared queries. spi_prepare accepts a query string with numbered argument placeholders ($1, $2, etc) and a string list of argument types:

```
$plan = spi_prepare('SELECT * FROM test WHERE id > $1 AND name = $2',
                                                    'INTEGER', 'TEXT');
```

Once a query plan is prepared by a call to spi_prepare, the plan can be used instead of the string query, either in spi_exec_prepared, where the result is the same as returned by spi_exec_query, or in spi_query_prepared which returns a cursor exactly as spi_query does, which can be later passed to spi_fetchrow. The optional second parameter to spi_exec_prepared is a hash reference of attributes; the only attribute currently supported is limit, which sets the maximum number of rows returned by a query.

The advantage of prepared queries is that is it possible to use one prepared plan for more than one query execution. After the plan is not needed anymore, it can be freed with spi_freeplan:

```
CREATE OR REPLACE FUNCTION init() RETURNS VOID AS $$
        $_SHARED{my_plan} = spi_prepare('SELECT (now() + $1)::date AS now',
                                        'INTERVAL');
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION add_time( INTERVAL ) RETURNS TEXT AS $$
        return spi_exec_prepared(
                $_SHARED{my_plan},
                $_[0]
        )->{rows}->[0]->{now};
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION done() RETURNS VOID AS $$
        spi_freeplan( $_SHARED{my_plan});
        undef $_SHARED{my_plan};
$$ LANGUAGE plperl;

SELECT init();
SELECT add_time('1 day'), add_time('2 days'), add_time('3 days');
SELECT done();

  add_time  |  add_time  |  add_time
------------+------------+------------
 2005-12-10 | 2005-12-11 | 2005-12-12
```

Note that the parameter subscript in spi_prepare is defined via $1, $2, $3, etc, so avoid declaring query strings in double quotes that might easily lead to hard-to-catch bugs.

Another example illustrates usage of an optional parameter in spi_exec_prepared:

```
CREATE TABLE hosts AS SELECT id, ('192.168.1.'||id)::inet AS address
                      FROM generate_series(1,3) AS id;

CREATE OR REPLACE FUNCTION init_hosts_query() RETURNS VOID AS $$
        $_SHARED{plan} = spi_prepare('SELECT * FROM hosts
                                      WHERE address << $1', 'inet');
```

```
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION query_hosts(inet) RETURNS SETOF hosts AS $$
        return spi_exec_prepared(
                $_SHARED{plan},
                {limit => 2},
                $_[0]
        )->{rows};
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION release_hosts_query() RETURNS VOID AS $$
        spi_freeplan($_SHARED{plan});
        undef $_SHARED{plan};
$$ LANGUAGE plperl;

SELECT init_hosts_query();
SELECT query_hosts('192.168.1.0/30');
SELECT release_hosts_query();

    query_hosts
-----------------
 (1,192.168.1.1)
 (2,192.168.1.2)
(2 rows)
```

42.3.2. Utility Functions in PL/Perl

`elog(`*`level`*`, `*`msg`*`)`

Emit a log or error message. Possible levels are `DEBUG`, `LOG`, `INFO`, `NOTICE`, `WARNING`, and `ERROR`. `ERROR` raises an error condition; if this is not trapped by the surrounding Perl code, the error propagates out to the calling query, causing the current transaction or subtransaction to be aborted. This is effectively the same as the Perl `die` command. The other levels only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log_min_messages and client_min_messages configuration variables. See Chapter 18 for more information.

`quote_literal(`*`string`*`)`

Return the given string suitably quoted to be used as a string literal in an SQL statement string. Embedded single-quotes and backslashes are properly doubled. Note that `quote_literal` returns undef on undef input; if the argument might be undef, `quote_nullable` is often more suitable.

`quote_nullable(`*`string`*`)`

Return the given string suitably quoted to be used as a string literal in an SQL statement string; or, if the argument is undef, return the unquoted string "NULL". Embedded single-quotes and backslashes are properly doubled.

`quote_ident(`*`string`*`)`

Return the given string suitably quoted to be used as an identifier in an SQL statement string. Quotes are added only if necessary (i.e., if the string contains non-identifier characters or would be case-folded). Embedded quotes are properly doubled.

`decode_bytea(string)`

Return the unescaped binary data represented by the contents of the given string, which should be `bytea` encoded.

`encode_bytea(string)`

Return the `bytea` encoded form of the binary data contents of the given string.

`encode_array_literal(array)`
`encode_array_literal(array, delimiter)`

Returns the contents of the referenced array as a string in array literal format (see Section 8.15.2). Returns the argument value unaltered if it's not a reference to an array. The delimiter used between elements of the array literal defaults to `", "` if a delimiter is not specified or is undef.

`encode_typed_literal(value, typename)`

Converts a Perl variable to the value of the data type passed as a second argument and returns a string representation of this value. Correctly handles nested arrays and values of composite types.

`encode_array_constructor(array)`

Returns the contents of the referenced array as a string in array constructor format (see Section 4.2.12). Individual values are quoted using `quote_nullable`. Returns the argument value, quoted using `quote_nullable`, if it's not a reference to an array.

`looks_like_number(string)`

Returns a true value if the content of the given string looks like a number, according to Perl, returns false otherwise. Returns undef if the argument is undef. Leading and trailing space is ignored. `Inf` and `Infinity` are regarded as numbers.

`is_array_ref(argument)`

Returns a true value if the given argument may be treated as an array reference, that is, if ref of the argument is `ARRAY` or `PostgreSQL::InServer::ARRAY`. Returns false otherwise.

42.4. Global Values in PL/Perl

You can use the global hash `%_SHARED` to store data, including code references, between function calls for the lifetime of the current session.

Here is a simple example for shared data:

```
CREATE OR REPLACE FUNCTION set_var(name text, val text) RETURNS text AS $$
    if ($_SHARED{$_[0]} = $_[1]) {
        return 'ok';
    } else {
        return "cannot set shared variable $_[0] to $_[1]";
    }
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION get_var(name text) RETURNS text AS $$
    return $_SHARED{$_[0]};
$$ LANGUAGE plperl;

SELECT set_var('sample', 'Hello, PL/Perl!  How"s tricks?');
SELECT get_var('sample');
```

Here is a slightly more complicated example using a code reference:

```
CREATE OR REPLACE FUNCTION myfuncs() RETURNS void AS $$
    $_SHARED{myquote} = sub {
        my $arg = shift;
        $arg =~ s/(['\\])/\\$1/g;
        return "'$arg'";
    };
$$ LANGUAGE plperl;

SELECT myfuncs(); /* initializes the function */

/* Set up a function that uses the quote function */

CREATE OR REPLACE FUNCTION use_quote(TEXT) RETURNS text AS $$
    my $text_to_quote = shift;
    my $qfunc = $_SHARED{myquote};
    return &$qfunc($text_to_quote);
$$ LANGUAGE plperl;
```

(You could have replaced the above with the one-liner `return $_SHARED{myquote}->($_[0]);` at the expense of readability.)

For security reasons, PL/Perl executes functions called by any one SQL role in a separate Perl interpreter for that role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Perl functions. Each such interpreter has its own value of the `%_SHARED` variable and other global state. Thus, two PL/Perl functions will share the same value of `%_SHARED` if and only if they are executed by the same SQL role. In an application wherein a single session executes code under multiple SQL roles (via `SECURITY DEFINER` functions, use of `SET ROLE`, etc) you may need to take explicit steps to ensure that PL/Perl functions can share data via `%_SHARED`. To do that, make sure that functions that should communicate are owned by the same user, and mark them `SECURITY DEFINER`. You must of course take care that such functions can't be used to do anything unintended.

42.5. Trusted and Untrusted PL/Perl

Normally, PL/Perl is installed as a "trusted" programming language named `plperl`. In this setup, certain Perl operations are disabled to preserve security. In general, the operations that are restricted are those that interact with the environment. This includes file handle operations, `require`, and `use` (for external modules). There is no way to access internals of the database server process or to gain OS-level access with the permissions of the server process, as a C function can do. Thus, any unprivileged database user can be permitted to use this language.

Here is an example of a function that will not work because file system operations are not allowed for security reasons:

```
CREATE FUNCTION badfunc() RETURNS integer AS $$
    my $tmpfile = "/tmp/badfile";
    open my $fh, '>', $tmpfile
        or elog(ERROR, qq{could not open the file "$tmpfile": $!});
    print $fh "Testing writing to a file\n";
    close $fh or elog(ERROR, qq{could not close the file "$tmpfile": $!});
    return 1;
$$ LANGUAGE plperl;
```

The creation of this function will fail as its use of a forbidden operation will be caught by the validator.

Sometimes it is desirable to write Perl functions that are not restricted. For example, one might want a Perl function that sends mail. To handle these cases, PL/Perl can also be installed as an "untrusted" language (usually called PL/PerlU). In this case the full Perl language is available. When installing the language, the language name `plperlu` will select the untrusted PL/Perl variant.

The writer of a PL/PerlU function must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator. Note that the database system allows only database superusers to create functions in untrusted languages.

If the above function was created by a superuser using the language `plperlu`, execution would succeed.

In the same way, anonymous code blocks written in Perl can use restricted operations if the language is specified as `plperlu` rather than `plperl`, but the caller must be a superuser.

> **Note:** While PL/Perl functions run in a separate Perl interpreter for each SQL role, all PL/PerlU functions executed in a given session run in a single Perl interpreter (which is not any of the ones used for PL/Perl functions). This allows PL/PerlU functions to share data freely, but no communication can occur between PL/Perl and PL/PerlU functions.

> **Note:** Perl cannot support multiple interpreters within one process unless it was built with the appropriate flags, namely either `usemultiplicity` or `useithreads`. (`usemultiplicity` is preferred unless you actually need to use threads. For more details, see the perlembed man page.) If PL/Perl is used with a copy of Perl that was not built this way, then it is only possible to have one Perl interpreter per session, and so any one session can only execute either PL/PerlU functions, or PL/Perl functions that are all called by the same SQL role.

42.6. PL/Perl Triggers

PL/Perl can be used to write trigger functions. In a trigger function, the hash reference `$_TD` contains information about the current trigger event. `$_TD` is a global variable, which gets a separate local value for each invocation of the trigger. The fields of the `$_TD` hash reference are:

`$_TD->{new}{foo}`

`NEW` value of column `foo`

`$_TD->{old}{foo}`

`OLD` value of column `foo`

`$_TD->{name}`

Name of the trigger being called

`$_TD->{event}`

Trigger event: `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE`, or `UNKNOWN`

`$_TD->{when}`

When the trigger was called: `BEFORE`, `AFTER`, `INSTEAD OF`, or `UNKNOWN`

`$_TD->{level}`

The trigger level: `ROW`, `STATEMENT`, or `UNKNOWN`

`$_TD->{relid}`

OID of the table on which the trigger fired

`$_TD->{table_name}`

Name of the table on which the trigger fired

`$_TD->{relname}`

Name of the table on which the trigger fired. This has been deprecated, and could be removed in a future release. Please use $_TD->{table_name} instead.

`$_TD->{table_schema}`

Name of the schema in which the table on which the trigger fired, is

`$_TD->{argc}`

Number of arguments of the trigger function

`@{$_TD->{args}}`

Arguments of the trigger function. Does not exist if `$_TD->{argc}` is 0.

Row-level triggers can return one of the following:

`return;`

Execute the operation

`"SKIP"`

Don't execute the operation

`"MODIFY"`

Indicates that the `NEW` row was modified by the trigger function

Here is an example of a trigger function, illustrating some of the above:

```
CREATE TABLE test (
    i int,
    v varchar
);

CREATE OR REPLACE FUNCTION valid_id() RETURNS trigger AS $$
    if (($_TD->{new}{i} >= 100) || ($_TD->{new}{i} <= 0)) {
        return "SKIP";    # skip INSERT/UPDATE command
    } elsif ($_TD->{new}{v} ne "immortal") {
        $_TD->{new}{v} .= "(modified by trigger)";
        return "MODIFY";  # modify row and execute INSERT/UPDATE command
    } else {
        return;           # execute INSERT/UPDATE command
    }
$$ LANGUAGE plperl;

CREATE TRIGGER test_valid_id_trig
    BEFORE INSERT OR UPDATE ON test
```

```
    FOR EACH ROW EXECUTE PROCEDURE valid_id();
```

42.7. PL/Perl Event Triggers

PL/Perl can be used to write event trigger functions. In an event trigger function, the hash reference `$_TD` contains information about the current trigger event. `$_TD` is a global variable, which gets a separate local value for each invocation of the trigger. The fields of the `$_TD` hash reference are:

`$_TD->{event}`

The name of the event the trigger is fired for.

`$_TD->{tag}`

The command tag for which the trigger is fired.

The return value of the trigger procedure is ignored.

Here is an example of an event trigger function, illustrating some of the above:

```
CREATE OR REPLACE FUNCTION perlsnitch() RETURNS event_trigger AS $$
  elog(NOTICE, "perlsnitch: " . $_TD->{event} . " " . $_TD->{tag} . " ");
$$ LANGUAGE plperl;

CREATE EVENT TRIGGER perl_a_snitch
    ON ddl_command_start
    EXECUTE PROCEDURE perlsnitch();
```

42.8. PL/Perl Under the Hood

42.8.1. Configuration

This section lists configuration parameters that affect PL/Perl.

`plperl.on_init` (`string`)

Specifies Perl code to be executed when a Perl interpreter is first initialized, before it is specialized for use by `plperl` or `plperlu`. The SPI functions are not available when this code is executed. If the code fails with an error it will abort the initialization of the interpreter and propagate out to the calling query, causing the current transaction or subtransaction to be aborted.

The Perl code is limited to a single string. Longer code can be placed into a module and loaded by the `on_init` string. Examples:

```
plperl.on_init = 'require "plperlinit.pl"'
plperl.on_init = 'use lib "/my/app"; use MyApp::PgInit;'
```

Any modules loaded by `plperl.on_init`, either directly or indirectly, will be available for use by `plperl`. This may create a security risk. To see what modules have been loaded you can use:

```
DO 'elog(WARNING, join ", ", sort keys %INC)' LANGUAGE plperl;
```

Initialization will happen in the postmaster if the plperl library is included in shared_preload_libraries, in which case extra consideration should be given to the risk of destabilizing the postmaster. The principal reason for making use of this feature is that Perl modules loaded by `plperl.on_init` need be loaded only at postmaster start, and will be instantly available without loading overhead in individual database sessions. However, keep in mind that the overhead is avoided only for the first Perl interpreter used by a database session — either PL/PerlU, or PL/Perl for the first SQL role that calls a PL/Perl function. Any additional Perl interpreters created in a database session will have to execute `plperl.on_init` afresh. Also, on Windows there will be no savings whatsoever from preloading, since the Perl interpreter created in the postmaster process does not propagate to child processes.

This parameter can only be set in the `postgresql.conf` file or on the server command line.

`plperl.on_plperl_init` (`string`)
`plperl.on_plperlu_init` (`string`)

These parameters specify Perl code to be executed when a Perl interpreter is specialized for `plperl` or `plperlu` respectively. This will happen when a PL/Perl or PL/PerlU function is first executed in a database session, or when an additional interpreter has to be created because the other language is called or a PL/Perl function is called by a new SQL role. This follows any initialization done by `plperl.on_init`. The SPI functions are not available when this code is executed. The Perl code in `plperl.on_plperl_init` is executed after "locking down" the interpreter, and thus it can only perform trusted operations.

If the code fails with an error it will abort the initialization and propagate out to the calling query, causing the current transaction or subtransaction to be aborted. Any actions already done within Perl won't be undone; however, that interpreter won't be used again. If the language is used again the initialization will be attempted again within a fresh Perl interpreter.

Only superusers can change these settings. Although these settings can be changed within a session, such changes will not affect Perl interpreters that have already been used to execute functions.

`plperl.use_strict` (`boolean`)

When set true subsequent compilations of PL/Perl functions will have the `strict` pragma enabled. This parameter does not affect functions already compiled in the current session.

42.8.2. Limitations and Missing Features

The following features are currently missing from PL/Perl, but they would make welcome contributions.

- PL/Perl functions cannot call each other directly.
- SPI is not yet fully implemented.
- If you are fetching very large data sets using `spi_exec_query`, you should be aware that these will all go into memory. You can avoid this by using `spi_query`/`spi_fetchrow` as illustrated earlier.

  A similar problem occurs if a set-returning function passes a large set of rows back to PostgreSQL via `return`. You can avoid this problem too by instead using `return_next` for each row returned, as shown previously.

- When a session ends normally, not due to a fatal error, any `END` blocks that have been defined are executed. Currently no other actions are performed. Specifically, file handles are not automatically flushed and objects are not automatically destroyed.

Chapter 43. PL/Python - Python Procedural Language

The PL/Python procedural language allows PostgreSQL functions to be written in the Python language[1].

To install PL/Python in a particular database, use `CREATE EXTENSION plpythonu`, or from the shell command line use `createlang plpythonu` *`dbname`* (but see also Section 43.1).

> **Tip:** If a language is installed into `template1`, all subsequently created databases will have the language installed automatically.

PL/Python is only available as an "untrusted" language, meaning it does not offer any way of restricting what users can do in it and is therefore named `plpythonu`. A trusted variant `plpython` might become available in the future if a secure execution mechanism is developed in Python. The writer of a function in untrusted PL/Python must take care that the function cannot be used to do anything unwanted, since it will be able to do anything that could be done by a user logged in as the database administrator. Only superusers can create functions in untrusted languages such as `plpythonu`.

> **Note:** Users of source packages must specially enable the build of PL/Python during the installation process. (Refer to the installation instructions for more information.) Users of binary packages might find PL/Python in a separate subpackage.

43.1. Python 2 vs. Python 3

PL/Python supports both the Python 2 and Python 3 language variants. (The PostgreSQL installation instructions might contain more precise information about the exact supported minor versions of Python.) Because the Python 2 and Python 3 language variants are incompatible in some important aspects, the following naming and transitioning scheme is used by PL/Python to avoid mixing them:

- The PostgreSQL language named `plpython2u` implements PL/Python based on the Python 2 language variant.
- The PostgreSQL language named `plpython3u` implements PL/Python based on the Python 3 language variant.
- The language named `plpythonu` implements PL/Python based on the default Python language variant, which is currently Python 2. (This default is independent of what any local Python installations might consider to be their "default", for example, what `/usr/bin/python` might be.) The default will probably be changed to Python 3 in a distant future release of PostgreSQL, depending on the progress of the migration to Python 3 in the Python community.

This scheme is analogous to the recommendations in PEP 394[2] regarding the naming and transitioning of the `python` command.

1. http://www.python.org
2. http://www.python.org/dev/peps/pep-0394/

It depends on the build configuration or the installed packages whether PL/Python for Python 2 or Python 3 or both are available.

> **Tip:** The built variant depends on which Python version was found during the installation or which version was explicitly set using the `PYTHON` environment variable; see Section 15.4. To make both variants of PL/Python available in one installation, the source tree has to be configured and built twice.

This results in the following usage and migration strategy:

- Existing users and users who are currently not interested in Python 3 use the language name `plpythonu` and don't have to change anything for the foreseeable future. It is recommended to gradually "future-proof" the code via migration to Python 2.6/2.7 to simplify the eventual migration to Python 3.

  In practice, many PL/Python functions will migrate to Python 3 with few or no changes.
- Users who know that they have heavily Python 2 dependent code and don't plan to ever change it can make use of the `plpython2u` language name. This will continue to work into the very distant future, until Python 2 support might be completely dropped by PostgreSQL.
- Users who want to dive into Python 3 can use the `plpython3u` language name, which will keep working forever by today's standards. In the distant future, when Python 3 might become the default, they might like to remove the "3" for aesthetic reasons.
- Daredevils, who want to build a Python-3-only operating system environment, can change the contents of `pg_pltemplate` to make `plpythonu` be equivalent to `plpython3u`, keeping in mind that this would make their installation incompatible with most of the rest of the world.

See also the document What's New In Python 3.0[3] for more information about porting to Python 3.

It is not allowed to use PL/Python based on Python 2 and PL/Python based on Python 3 in the same session, because the symbols in the dynamic modules would clash, which could result in crashes of the PostgreSQL server process. There is a check that prevents mixing Python major versions in a session, which will abort the session if a mismatch is detected. It is possible, however, to use both PL/Python variants in the same database, from separate sessions.

43.2. PL/Python Functions

Functions in PL/Python are declared via the standard CREATE FUNCTION syntax:

```
CREATE FUNCTION funcname (argument-list)
  RETURNS return-type
AS $$
  # PL/Python function body
$$ LANGUAGE plpythonu;
```

3. http://docs.python.org/py3k/whatsnew/3.0.html

The body of a function is simply a Python script. When the function is called, its arguments are passed as elements of the list `args`; named arguments are also passed as ordinary variables to the Python script. Use of named arguments is usually more readable. The result is returned from the Python code in the usual way, with `return` or `yield` (in case of a result-set statement). If you do not provide a return value, Python returns the default `None`. PL/Python translates Python's `None` into the SQL null value.

For example, a function to return the greater of two integers can be defined as:

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer
AS $$
  if a > b:
    return a
  return b
$$ LANGUAGE plpythonu;
```

The Python code that is given as the body of the function definition is transformed into a Python function. For example, the above results in:

```
def __plpython_procedure_pymax_23456():
  if a > b:
    return a
  return b
```

assuming that 23456 is the OID assigned to the function by PostgreSQL.

The arguments are set as global variables. Because of the scoping rules of Python, this has the subtle consequence that an argument variable cannot be reassigned inside the function to the value of an expression that involves the variable name itself, unless the variable is redeclared as global in the block. For example, the following won't work:

```
CREATE FUNCTION pystrip(x text)
  RETURNS text
AS $$
  x = x.strip()  # error
  return x
$$ LANGUAGE plpythonu;
```

because assigning to `x` makes `x` a local variable for the entire block, and so the `x` on the right-hand side of the assignment refers to a not-yet-assigned local variable `x`, not the PL/Python function parameter. Using the `global` statement, this can be made to work:

```
CREATE FUNCTION pystrip(x text)
  RETURNS text
AS $$
  global x
  x = x.strip()  # ok now
  return x
$$ LANGUAGE plpythonu;
```

But it is advisable not to rely on this implementation detail of PL/Python. It is better to treat the function parameters as read-only.

43.3. Data Values

Generally speaking, the aim of PL/Python is to provide a "natural" mapping between the PostgreSQL and the Python worlds. This informs the data mapping rules described below.

43.3.1. Data Type Mapping

Function arguments are converted from their PostgreSQL type to a corresponding Python type:

- PostgreSQL `boolean` is converted to Python `bool`.
- PostgreSQL `smallint` and `int` are converted to Python `int`. PostgreSQL `bigint` and `oid` are converted to `long` in Python 2 and to `int` in Python 3.
- PostgreSQL `real` and `double` are converted to Python `float`.
- PostgreSQL `numeric` is converted to Python `Decimal`. This type is imported from the `cdecimal` package if that is available. Otherwise, `decimal.Decimal` from the standard library will be used. `cdecimal` is significantly faster than `decimal`. In Python 3.3, however, `cdecimal` has been integrated into the standard library under the name `decimal`, so there is no longer any difference.
- PostgreSQL `bytea` is converted to Python `str` in Python 2 and to `bytes` in Python 3. In Python 2, the string should be treated as a byte sequence without any character encoding.
- All other data types, including the PostgreSQL character string types, are converted to a Python `str`. In Python 2, this string will be in the PostgreSQL server encoding; in Python 3, it will be a Unicode string like all strings.
- For nonscalar data types, see below.

Function return values are converted to the declared PostgreSQL return data type as follows:

- When the PostgreSQL return type is `boolean`, the return value will be evaluated for truth according to the *Python* rules. That is, 0 and empty string are false, but notably `'f'` is true.
- When the PostgreSQL return type is `bytea`, the return value will be converted to a string (Python 2) or bytes (Python 3) using the respective Python built-ins, with the result being converted `bytea`.
- For all other PostgreSQL return types, the returned Python value is converted to a string using the Python built-in `str`, and the result is passed to the input function of the PostgreSQL data type.

  Strings in Python 2 are required to be in the PostgreSQL server encoding when they are passed to PostgreSQL. Strings that are not valid in the current server encoding will raise an error, but not all encoding mismatches can be detected, so garbage data can still result when this is not done correctly. Unicode strings are converted to the correct encoding automatically, so it can be safer and more convenient to use those. In Python 3, all strings are Unicode strings.
- For nonscalar data types, see below.

Note that logical mismatches between the declared PostgreSQL return type and the Python data type of the actual return object are not flagged; the value will be converted in any case.

43.3.2. Null, None

If an SQL null value is passed to a function, the argument value will appear as `None` in Python. For example, the function definition of `pymax` shown in Section 43.2 will return the wrong answer for null inputs. We could add `STRICT` to the function definition to make PostgreSQL do something more reasonable: if a null value is passed, the function will not be called at all, but will just return a null result automatically. Alternatively, we could check for null inputs in the function body:

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer
AS $$
  if (a is None) or (b is None):
    return None
  if a > b:
    return a
  return b
$$ LANGUAGE plpythonu;
```

As shown above, to return an SQL null value from a PL/Python function, return the value `None`. This can be done whether the function is strict or not.

43.3.3. Arrays, Lists

SQL array values are passed into PL/Python as a Python list. To return an SQL array value out of a PL/Python function, return a Python sequence, for example a list or tuple:

```
CREATE FUNCTION return_arr()
  RETURNS int[]
AS $$
return (1, 2, 3, 4, 5)
$$ LANGUAGE plpythonu;

SELECT return_arr();
 return_arr
-------------
 {1,2,3,4,5}
(1 row)
```

Note that in Python, strings are sequences, which can have undesirable effects that might be familiar to Python programmers:

```
CREATE FUNCTION return_str_arr()
  RETURNS varchar[]
AS $$
return "hello"
$$ LANGUAGE plpythonu;

SELECT return_str_arr();
 return_str_arr
----------------
 {h,e,l,l,o}
(1 row)
```

43.3.4. Composite Types

Composite-type arguments are passed to the function as Python mappings. The element names of the mapping are the attribute names of the composite type. If an attribute in the passed row has the null value, it has the value `None` in the mapping. Here is an example:

```
CREATE TABLE employee (
  name text,
  salary integer,
  age integer
);

CREATE FUNCTION overpaid (e employee)
  RETURNS boolean
AS $$
  if e["salary"] > 200000:
    return True
  if (e["age"] < 30) and (e["salary"] > 100000):
    return True
  return False
$$ LANGUAGE plpythonu;
```

There are multiple ways to return row or composite types from a Python function. The following examples assume we have:

```
CREATE TYPE named_value AS (
  name   text,
  value  integer
);
```

A composite result can be returned as a:

Sequence type (a tuple or list, but not a set because it is not indexable)

> Returned sequence objects must have the same number of items as the composite result type has fields. The item with index 0 is assigned to the first field of the composite type, 1 to the second and so on. For example:
>
> ```
> CREATE FUNCTION make_pair (name text, value integer)
>   RETURNS named_value
> AS $$
>   return [ name, value ]
>   # or alternatively, as tuple: return ( name, value )
> $$ LANGUAGE plpythonu;
> ```
>
> To return a SQL null for any column, insert `None` at the corresponding position.

Mapping (dictionary)

> The value for each result type column is retrieved from the mapping with the column name as key. Example:
>
> ```
> CREATE FUNCTION make_pair (name text, value integer)
>   RETURNS named_value
> AS $$
>   return { "name": name, "value": value }
> $$ LANGUAGE plpythonu;
> ```

Any extra dictionary key/value pairs are ignored. Missing keys are treated as errors. To return a SQL null value for any column, insert `None` with the corresponding column name as the key.

Object (any object providing method `__getattr__`)

This works the same as a mapping. Example:

```
CREATE FUNCTION make_pair (name text, value integer)
  RETURNS named_value
AS $$
  class named_value:
    def __init__ (self, n, v):
      self.name = n
      self.value = v
  return named_value(name, value)

  # or simply
  class nv: pass
  nv.name = name
  nv.value = value
  return nv
$$ LANGUAGE plpythonu;
```

Functions with `OUT` parameters are also supported. For example:

```
CREATE FUNCTION multiout_simple(OUT i integer, OUT j integer) AS $$
return (1, 2)
$$ LANGUAGE plpythonu;

SELECT * FROM multiout_simple();
```

43.3.5. Set-returning Functions

A PL/Python function can also return sets of scalar or composite types. There are several ways to achieve this because the returned object is internally turned into an iterator. The following examples assume we have composite type:

```
CREATE TYPE greeting AS (
  how text,
  who text
);
```

A set result can be returned from a:

Sequence type (tuple, list, set)

```
CREATE FUNCTION greet (how text)
  RETURNS SETOF greeting
AS $$
  # return tuple containing lists as composite types
  # all other combinations work also
  return ( [ how, "World" ], [ how, "PostgreSQL" ], [ how, "PL/Python" ] )
$$ LANGUAGE plpythonu;
```

Iterator (any object providing `__iter__` and `next` methods)

```
CREATE FUNCTION greet (how text)
  RETURNS SETOF greeting
AS $$
  class producer:
    def __init__ (self, how, who):
      self.how = how
      self.who = who
      self.ndx = -1

    def __iter__ (self):
      return self

    def next (self):
      self.ndx += 1
      if self.ndx == len(self.who):
        raise StopIteration
      return ( self.how, self.who[self.ndx] )

  return producer(how, [ "World", "PostgreSQL", "PL/Python" ])
$$ LANGUAGE plpythonu;
```

Generator (`yield`)

```
CREATE FUNCTION greet (how text)
  RETURNS SETOF greeting
AS $$
  for who in [ "World", "PostgreSQL", "PL/Python" ]:
    yield ( how, who )
$$ LANGUAGE plpythonu;
```

Warning

Due to Python bug #1483133[4], some debug versions of Python 2.4 (configured and compiled with option `--with-pydebug`) are known to crash the PostgreSQL server when using an iterator to return a set result. Unpatched versions of Fedora 4 contain this bug. It does not happen in production versions of Python or on patched versions of Fedora 4.

Set-returning functions with `OUT` parameters (using `RETURNS SETOF record`) are also supported. For example:

```
CREATE FUNCTION multiout_simple_setof(n integer, OUT integer, OUT integer) RETURNS SETOF
return [(1, 2)] * n
$$ LANGUAGE plpythonu;

SELECT * FROM multiout_simple_setof(3);
```

43.4. Sharing Data

The global dictionary `SD` is available to store data between function calls. This variable is private static data. The global dictionary `GD` is public data, available to all Python functions within a session. Use with care.

Each function gets its own execution environment in the Python interpreter, so that global data and function arguments from `myfunc` are not available to `myfunc2`. The exception is the data in the `GD` dictionary, as mentioned above.

43.5. Anonymous Code Blocks

PL/Python also supports anonymous code blocks called with the DO statement:

```
DO $$
    # PL/Python code
$$ LANGUAGE plpythonu;
```

An anonymous code block receives no arguments, and whatever value it might return is discarded. Otherwise it behaves just like a function.

43.6. Trigger Functions

When a function is used as a trigger, the dictionary `TD` contains trigger-related values:

`TD["event"]`

contains the event as a string: `INSERT`, `UPDATE`, `DELETE`, or `TRUNCATE`.

`TD["when"]`

contains one of `BEFORE`, `AFTER`, or `INSTEAD OF`.

`TD["level"]`

contains `ROW` or `STATEMENT`.

`TD["new"]`
`TD["old"]`

For a row-level trigger, one or both of these fields contain the respective trigger rows, depending on the trigger event.

`TD["name"]`

contains the trigger name.

`TD["table_name"]`

contains the name of the table on which the trigger occurred.

`TD["table_schema"]`

contains the schema of the table on which the trigger occurred.

`TD["relid"]`

contains the OID of the table on which the trigger occurred.

`TD["args"]`

If the `CREATE TRIGGER` command included arguments, they are available in `TD["args"][0]` to `TD["args"][n-1]`.

If `TD["when"]` is `BEFORE` or `INSTEAD OF` and `TD["level"]` is `ROW`, you can return `None` or `"OK"` from the Python function to indicate the row is unmodified, `"SKIP"` to abort the event, or if `TD["event"]` is `INSERT` or `UPDATE` you can return `"MODIFY"` to indicate you've modified the new row. Otherwise the return value is ignored.

43.7. Database Access

The PL/Python language module automatically imports a Python module called `plpy`. The functions and constants in this module are available to you in the Python code as `plpy.foo`.

43.7.1. Database Access Functions

The `plpy` module provides several functions to execute database commands:

`plpy.execute(query [, max-rows])`

Calling `plpy.execute` with a query string and an optional row limit argument causes that query to be run and the result to be returned in a result object.

The result object emulates a list or dictionary object. The result object can be accessed by row number and column name. For example:

```
rv = plpy.execute("SELECT * FROM my_table", 5)
```

returns up to 5 rows from `my_table`. If `my_table` has a column `my_column`, it would be accessed as:

```
foo = rv[i]["my_column"]
```

The number of rows returned can be obtained using the built-in `len` function.

The result object has these additional methods:

`nrows()`

Returns the number of rows processed by the command. Note that this is not necessarily the same as the number of rows returned. For example, an `UPDATE` command will set this value but won't return any rows (unless `RETURNING` is used).

`status()`

The `SPI_execute()` return value.

`colnames()`
`coltypes()`
`coltypmods()`

Return a list of column names, list of column type OIDs, and list of type-specific type modifiers for the columns, respectively.

These methods raise an exception when called on a result object from a command that did not produce a result set, e.g., `UPDATE` without `RETURNING`, or `DROP TABLE`. But it is OK to use these methods on a result set containing zero rows.

`__str__()`

The standard `__str__` method is defined so that it is possible for example to debug query execution results using `plpy.debug(rv)`.

The result object can be modified.

Note that calling `plpy.execute` will cause the entire result set to be read into memory. Only use that function when you are sure that the result set will be relatively small. If you don't want to risk excessive memory usage when fetching large results, use `plpy.cursor` rather than `plpy.execute`.

`plpy.prepare(`*query* `[, `*argtypes*`])`
`plpy.execute(`*plan* `[, `*arguments* `[, `*max-rows*`]])`

`plpy.prepare` prepares the execution plan for a query. It is called with a query string and a list of parameter types, if you have parameter references in the query. For example:

```
plan = plpy.prepare("SELECT last_name FROM my_users WHERE first_name = $1", ["text"]
```

`text` is the type of the variable you will be passing for `$1`. The second argument is optional if you don't want to pass any parameters to the query.

After preparing a statement, you use a variant of the function `plpy.execute` to run it:

```
rv = plpy.execute(plan, ["name"], 5)
```

Pass the plan as the first argument (instead of the query string), and a list of values to substitute into the query as the second argument. The second argument is optional if the query does not expect any parameters. The third argument is the optional row limit as before.

Query parameters and result row fields are converted between PostgreSQL and Python data types as described in Section 43.3. The exception is that composite types are currently not supported: They will be rejected as query parameters and are converted to strings when appearing in a query result. As a workaround for the latter problem, the query can sometimes be rewritten so that the composite type result appears as a result row rather than as a field of the result row. Alternatively, the resulting string could be parsed apart by hand, but this approach is not recommended because it is not future-proof.

When you prepare a plan using the PL/Python module it is automatically saved. Read the SPI documentation (Chapter 44) for a description of what this means. In order to make effective use of this across function calls one needs to use one of the persistent storage dictionaries `SD` or `GD` (see Section 43.4). For example:

```
CREATE FUNCTION usesavedplan() RETURNS trigger AS $$
    if "plan" in SD:
        plan = SD["plan"]
    else:
        plan = plpy.prepare("SELECT 1")
        SD["plan"] = plan
    # rest of function
$$ LANGUAGE plpythonu;
```

`plpy.cursor(`*query*`)`
`plpy.cursor(`*plan* `[, `*arguments*`])`

The `plpy.cursor` function accepts the same arguments as `plpy.execute` (except for the row limit) and returns a cursor object, which allows you to process large result sets in smaller chunks. As with `plpy.execute`, either a query string or a plan object along with a list of arguments can be used.

The cursor object provides a `fetch` method that accepts an integer parameter and returns a result object. Each time you call `fetch`, the returned object will contain the next batch of rows, never larger than the parameter value. Once all rows are exhausted, `fetch` starts returning an empty result object. Cursor objects also provide an iterator interface[5], yielding one row at a time until all rows are exhausted. Data fetched that way is not returned as result objects, but rather as dictionaries, each dictionary corresponding to a single result row.

An example of two ways of processing data from a large table is:

```
CREATE FUNCTION count_odd_iterator() RETURNS integer AS $$
odd = 0
for row in plpy.cursor("select num from largetable"):
    if row['num'] % 2:
         odd += 1
return odd
$$ LANGUAGE plpythonu;

CREATE FUNCTION count_odd_fetch(batch_size integer) RETURNS integer AS $$
odd = 0
cursor = plpy.cursor("select num from largetable")
while True:
    rows = cursor.fetch(batch_size)
    if not rows:
        break
    for row in rows:
        if row['num'] % 2:
            odd += 1
return odd
$$ LANGUAGE plpythonu;

CREATE FUNCTION count_odd_prepared() RETURNS integer AS $$
odd = 0
plan = plpy.prepare("select num from largetable where num % $1 <> 0", ["integer"])
rows = list(plpy.cursor(plan, [2]))

return len(rows)
$$ LANGUAGE plpythonu;
```

Cursors are automatically disposed of. But if you want to explicitly release all resources held by a cursor, use the `close` method. Once closed, a cursor cannot be fetched from anymore.

> **Tip:** Do not confuse objects created by `plpy.cursor` with DB-API cursors as defined by the Python Database API specification[6]. They don't have anything in common except for the name.

43.7.2. Trapping Errors

Functions accessing the database might encounter errors, which will cause them to abort and raise an exception. Both `plpy.execute` and `plpy.prepare` can raise an instance of a subclass of

5. http://docs.python.org/library/stdtypes.html#iterator-types
6. http://www.python.org/dev/peps/pep-0249/

plpy.SPIError, which by default will terminate the function. This error can be handled just like any other Python exception, by using the try/except construct. For example:

```
CREATE FUNCTION try_adding_joe() RETURNS text AS $$
    try:
        plpy.execute("INSERT INTO users(username) VALUES ('joe')")
    except plpy.SPIError:
        return "something went wrong"
    else:
        return "Joe added"
$$ LANGUAGE plpythonu;
```

The actual class of the exception being raised corresponds to the specific condition that caused the error. Refer to Table A-1 for a list of possible conditions. The module plpy.spiexceptions defines an exception class for each PostgreSQL condition, deriving their names from the condition name. For instance, division_by_zero becomes DivisionByZero, unique_violation becomes UniqueViolation, fdw_error becomes FdwError, and so on. Each of these exception classes inherits from SPIError. This separation makes it easier to handle specific errors, for instance:

```
CREATE FUNCTION insert_fraction(numerator int, denominator int) RETURNS text AS $$
from plpy import spiexceptions
try:
    plan = plpy.prepare("INSERT INTO fractions (frac) VALUES ($1 / $2)", ["int", "int"])
    plpy.execute(plan, [numerator, denominator])
except spiexceptions.DivisionByZero:
    return "denominator cannot equal zero"
except spiexceptions.UniqueViolation:
    return "already have that fraction"
except plpy.SPIError, e:
    return "other error, SQLSTATE %s" % e.sqlstate
else:
    return "fraction inserted"
$$ LANGUAGE plpythonu;
```

Note that because all exceptions from the plpy.spiexceptions module inherit from SPIError, an except clause handling it will catch any database access error.

As an alternative way of handling different error conditions, you can catch the SPIError exception and determine the specific error condition inside the except block by looking at the sqlstate attribute of the exception object. This attribute is a string value containing the "SQLSTATE" error code. This approach provides approximately the same functionality

43.8. Explicit Subtransactions

Recovering from errors caused by database access as described in Section 43.7.2 can lead to an undesirable situation where some operations succeed before one of them fails, and after recovering from that error the data is left in an inconsistent state. PL/Python offers a solution to this problem in the form of explicit subtransactions.

43.8.1. Subtransaction Context Managers

Consider a function that implements a transfer between two accounts:

```
CREATE FUNCTION transfer_funds() RETURNS void AS $$
try:
    plpy.execute("UPDATE accounts SET balance = balance - 100 WHERE account_name = 'joe'
    plpy.execute("UPDATE accounts SET balance = balance + 100 WHERE account_name = 'mary
except plpy.SPIError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"
plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)", ["text"])
plpy.execute(plan, [result])
$$ LANGUAGE plpythonu;
```

If the second `UPDATE` statement results in an exception being raised, this function will report the error, but the result of the first `UPDATE` will nevertheless be committed. In other words, the funds will be withdrawn from Joe's account, but will not be transferred to Mary's account.

To avoid such issues, you can wrap your `plpy.execute` calls in an explicit subtransaction. The `plpy` module provides a helper object to manage explicit subtransactions that gets created with the `plpy.subtransaction()` function. Objects created by this function implement the context manager interface[7]. Using explicit subtransactions we can rewrite our function as:

```
CREATE FUNCTION transfer_funds2() RETURNS void AS $$
try:
    with plpy.subtransaction():
        plpy.execute("UPDATE accounts SET balance = balance - 100 WHERE account_name = '
        plpy.execute("UPDATE accounts SET balance = balance + 100 WHERE account_name = '
except plpy.SPIError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"
plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)", ["text"])
plpy.execute(plan, [result])
$$ LANGUAGE plpythonu;
```

Note that the use of `try/catch` is still required. Otherwise the exception would propagate to the top of the Python stack and would cause the whole function to abort with a PostgreSQL error, so that the `operations` table would not have any row inserted into it. The subtransaction context manager does not trap errors, it only assures that all database operations executed inside its scope will be atomically committed or rolled back. A rollback of the subtransaction block occurs on any kind of exception exit, not only ones caused by errors originating from database access. A regular Python exception raised inside an explicit subtransaction block would also cause the subtransaction to be rolled back.

43.8.2. Older Python Versions

Context managers syntax using the `with` keyword is available by default in Python 2.6. If using PL/Python with an older Python version, it is still possible to use explicit subtransactions, although not as transparently. You can call the subtransaction manager's `__enter__` and `__exit__` functions

7. http://docs.python.org/library/stdtypes.html#context-manager-types

using the `enter` and `exit` convenience aliases. The example function that transfers funds could be written as:

```
CREATE FUNCTION transfer_funds_old() RETURNS void AS $$
try:
    subxact = plpy.subtransaction()
    subxact.enter()
    try:
        plpy.execute("UPDATE accounts SET balance = balance - 100 WHERE account_name = '
        plpy.execute("UPDATE accounts SET balance = balance + 100 WHERE account_name = '
    except:
        import sys
        subxact.exit(*sys.exc_info())
        raise
    else:
        subxact.exit(None, None, None)
except plpy.SPIError, e:
    result = "error transferring funds: %s" % e.args
else:
    result = "funds transferred correctly"

plan = plpy.prepare("INSERT INTO operations (result) VALUES ($1)", ["text"])
plpy.execute(plan, [result])
$$ LANGUAGE plpythonu;
```

Note: Although context managers were implemented in Python 2.5, to use the `with` syntax in that version you need to use a future statement[8]. Because of implementation details, however, you cannot use future statements in PL/Python functions.

43.9. Utility Functions

The `plpy` module also provides the functions `plpy.debug(msg)`, `plpy.log(msg)`, `plpy.info(msg)`, `plpy.notice(msg)`, `plpy.warning(msg)`, `plpy.error(msg)`, and `plpy.fatal(msg)`. `plpy.error` and `plpy.fatal` actually raise a Python exception which, if uncaught, propagates out to the calling query, causing the current transaction or subtransaction to be aborted. `raise plpy.Error(msg)` and `raise plpy.Fatal(msg)` are equivalent to calling `plpy.error` and `plpy.fatal`, respectively. The other functions only generate messages of different priority levels. Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the log_min_messages and client_min_messages configuration variables. See Chapter 18 for more information.

Another set of utility functions are `plpy.quote_literal(string)`, `plpy.quote_nullable(string)`, and `plpy.quote_ident(string)`. They are equivalent to the built-in quoting functions described in Section 9.4. They are useful when constructing ad-hoc queries. A PL/Python equivalent of dynamic SQL from Example 40-1 would be:

```
plpy.execute("UPDATE tbl SET %s = %s WHERE key = %s" % (
    plpy.quote_ident(colname),
```

8. http://docs.python.org/release/2.5/ref/future.html

```
    plpy.quote_nullable(newvalue),
    plpy.quote_literal(keyvalue)))
```

43.10. Environment Variables

Some of the environment variables that are accepted by the Python interpreter can also be used to affect PL/Python behavior. They would need to be set in the environment of the main PostgreSQL server process, for example in a start script. The available environment variables depend on the version of Python; see the Python documentation for details. At the time of this writing, the following environment variables have an affect on PL/Python, assuming an adequate Python version:

- `PYTHONHOME`
- `PYTHONPATH`
- `PYTHONY2K`
- `PYTHONOPTIMIZE`
- `PYTHONDEBUG`
- `PYTHONVERBOSE`
- `PYTHONCASEOK`
- `PYTHONDONTWRITEBYTECODE`
- `PYTHONIOENCODING`
- `PYTHONUSERBASE`
- `PYTHONHASHSEED`

(It appears to be a Python implementation detail beyond the control of PL/Python that some of the environment variables listed on the `python` man page are only effective in a command-line interpreter and not an embedded Python interpreter.)

Chapter 44. Server Programming Interface

The *Server Programming Interface* (SPI) gives writers of user-defined C functions the ability to run SQL commands inside their functions. SPI is a set of interface functions to simplify access to the parser, planner, and executor. SPI also does some memory management.

> **Note:** The available procedural languages provide various means to execute SQL commands from procedures. Most of these facilities are based on SPI, so this documentation might be of use for users of those languages as well.

To avoid misunderstanding we'll use the term "function" when we speak of SPI interface functions and "procedure" for a user-defined C-function that is using SPI.

Note that if a command invoked via SPI fails, then control will not be returned to your procedure. Rather, the transaction or subtransaction in which your procedure executes will be rolled back. (This might seem surprising given that the SPI functions mostly have documented error-return conventions. Those conventions only apply for errors detected within the SPI functions themselves, however.) It is possible to recover control after an error by establishing your own subtransaction surrounding SPI calls that might fail. This is not currently documented because the mechanisms required are still in flux.

SPI functions return a nonnegative result on success (either via a returned integer value or in the global variable `SPI_result`, as described below). On error, a negative result or `NULL` will be returned.

Source code files that use SPI must include the header file `executor/spi.h`.

44.1. Interface Functions

SPI_connect

Name

`SPI_connect` — connect a procedure to the SPI manager

Synopsis

```
int SPI_connect(void)
```

Description

`SPI_connect` opens a connection from a procedure invocation to the SPI manager. You must call this function if you want to execute commands through SPI. Some utility SPI functions can be called from unconnected procedures.

If your procedure is already connected, `SPI_connect` will return the error code SPI_ERROR_CONNECT. This could happen if a procedure that has called `SPI_connect` directly

calls another procedure that calls `SPI_connect`. While recursive calls to the SPI manager are permitted when an SQL command called through SPI invokes another function that uses SPI, directly nested calls to `SPI_connect` and `SPI_finish` are forbidden. (But see `SPI_push` and `SPI_pop`.)

Return Value

`SPI_OK_CONNECT`

: on success

`SPI_ERROR_CONNECT`

: on error

SPI_finish

Name

`SPI_finish` — disconnect a procedure from the SPI manager

Synopsis

```
int SPI_finish(void)
```

Description

`SPI_finish` closes an existing connection to the SPI manager. You must call this function after completing the SPI operations needed during your procedure's current invocation. You do not need to worry about making this happen, however, if you abort the transaction via `elog(ERROR)`. In that case SPI will clean itself up automatically.

If `SPI_finish` is called without having a valid connection, it will return `SPI_ERROR_UNCONNECTED`. There is no fundamental problem with this; it means that the SPI manager has nothing to do.

Return Value

`SPI_OK_FINISH`

: if properly disconnected

`SPI_ERROR_UNCONNECTED`

: if called from an unconnected procedure

SPI_push

Name

SPI_push — push SPI stack to allow recursive SPI usage

Synopsis

```
void SPI_push(void)
```

Description

SPI_push should be called before executing another procedure that might itself wish to use SPI. After SPI_push, SPI is no longer in a "connected" state, and SPI function calls will be rejected unless a fresh SPI_connect is done. This ensures a clean separation between your procedure's SPI state and that of another procedure you call. After the other procedure returns, call SPI_pop to restore access to your own SPI state.

Note that SPI_execute and related functions automatically do the equivalent of SPI_push before passing control back to the SQL execution engine, so it is not necessary for you to worry about this when using those functions. Only when you are directly calling arbitrary code that might contain SPI_connect calls do you need to issue SPI_push and SPI_pop.

SPI_pop

Name

`SPI_pop` — pop SPI stack to return from recursive SPI usage

Synopsis

```
void SPI_pop(void)
```

Description

`SPI_pop` pops the previous environment from the SPI call stack. See `SPI_push`.

SPI_execute

Name

SPI_execute — execute a command

Synopsis

```
int SPI_execute(const char * command, bool read_only, long count)
```

Description

SPI_execute executes the specified SQL command for count rows. If read_only is true, the command must be read-only, and execution overhead is somewhat reduced.

This function can only be called from a connected procedure.

If count is zero then the command is executed for all rows that it applies to. If count is greater than zero, then no more than count rows will be retrieved; execution stops when the count is reached, much like adding a LIMIT clause to the query. For example,

```
SPI_execute("SELECT * FROM foo", true, 5);
```

will retrieve at most 5 rows from the table. Note that such a limit is only effective when the command actually returns rows. For example,

```
SPI_execute("INSERT INTO foo SELECT * FROM bar", false, 5);
```

inserts all rows from bar, ignoring the count parameter. However, with

```
SPI_execute("INSERT INTO foo SELECT * FROM bar RETURNING *", false, 5);
```

at most 5 rows would be inserted, since execution would stop after the fifth RETURNING result row is retrieved.

You can pass multiple commands in one string; SPI_execute returns the result for the command executed last. The count limit applies to each command separately (even though only the last result will actually be returned). The limit is not applied to any hidden commands generated by rules.

When read_only is false, SPI_execute increments the command counter and computes a new *snapshot* before executing each command in the string. The snapshot does not actually change if the current transaction isolation level is SERIALIZABLE or REPEATABLE READ, but in READ COMMITTED mode the snapshot update allows each command to see the results of newly committed transactions from other sessions. This is essential for consistent behavior when the commands are modifying the database.

When read_only is true, SPI_execute does not update either the snapshot or the command counter, and it allows only plain SELECT commands to appear in the command string. The commands are executed using the snapshot previously established for the surrounding query. This execution mode is somewhat faster than the read/write mode due to eliminating per-command overhead. It also allows genuinely *stable* functions to be built: since successive executions will all use the same snapshot, there will be no change in the results.

It is generally unwise to mix read-only and read-write commands within a single function using SPI; that could result in very confusing behavior, since the read-only queries would not see the results of any database updates done by the read-write queries.

The actual number of rows for which the (last) command was executed is returned in the global variable `SPI_processed`. If the return value of the function is `SPI_OK_SELECT`, `SPI_OK_INSERT_RETURNING`, `SPI_OK_DELETE_RETURNING`, or `SPI_OK_UPDATE_RETURNING`, then you can use the global pointer `SPITupleTable *SPI_tuptable` to access the result rows. Some utility commands (such as `EXPLAIN`) also return row sets, and `SPI_tuptable` will contain the result in these cases too. Some utility commands (`COPY`, `CREATE TABLE AS`) don't return a row set, so `SPI_tuptable` is NULL, but they still return the number of rows processed in `SPI_processed`.

The structure `SPITupleTable` is defined thus:

```
typedef struct
{
    MemoryContext tuptabcxt;    /* memory context of result table */
    uint32      alloced;        /* number of alloced vals */
    uint32      free;           /* number of free vals */
    TupleDesc   tupdesc;        /* row descriptor */
    HeapTuple  *vals;           /* rows */
} SPITupleTable;
```

`vals` is an array of pointers to rows. (The number of valid entries is given by `SPI_processed`.) `tupdesc` is a row descriptor which you can pass to SPI functions dealing with rows. `tuptabcxt`, `alloced`, and `free` are internal fields not intended for use by SPI callers.

`SPI_finish` frees all `SPITupleTable`s allocated during the current procedure. You can free a particular result table earlier, if you are done with it, by calling `SPI_freetuptable`.

Arguments

`const char * command`

string containing command to execute

`bool read_only`

`true` for read-only execution

`long count`

maximum number of rows to return, or `0` for no limit

Return Value

If the execution of the command was successful then one of the following (nonnegative) values will be returned:

`SPI_OK_SELECT`

if a `SELECT` (but not `SELECT INTO`) was executed

`SPI_OK_SELINTO`

if a `SELECT INTO` was executed

`SPI_OK_INSERT`

if an `INSERT` was executed

`SPI_OK_DELETE`

if a `DELETE` was executed

`SPI_OK_UPDATE`

if an `UPDATE` was executed

`SPI_OK_INSERT_RETURNING`

if an `INSERT RETURNING` was executed

`SPI_OK_DELETE_RETURNING`

if a `DELETE RETURNING` was executed

`SPI_OK_UPDATE_RETURNING`

if an `UPDATE RETURNING` was executed

`SPI_OK_UTILITY`

if a utility command (e.g., `CREATE TABLE`) was executed

`SPI_OK_REWRITTEN`

if the command was rewritten into another kind of command (e.g., `UPDATE` became an `INSERT`) by a rule.

On error, one of the following negative values is returned:

`SPI_ERROR_ARGUMENT`

if `command` is `NULL` or `count` is less than 0

`SPI_ERROR_COPY`

if `COPY TO stdout` or `COPY FROM stdin` was attempted

`SPI_ERROR_TRANSACTION`

if a transaction manipulation command was attempted (`BEGIN`, `COMMIT`, `ROLLBACK`, `SAVEPOINT`, `PREPARE TRANSACTION`, `COMMIT PREPARED`, `ROLLBACK PREPARED`, or any variant thereof)

`SPI_ERROR_OPUNKNOWN`

if the command type is unknown (shouldn't happen)

`SPI_ERROR_UNCONNECTED`

if called from an unconnected procedure

Notes

All SPI query-execution functions set both `SPI_processed` and `SPI_tuptable` (just the pointer, not the contents of the structure). Save these two global variables into local procedure variables if you need to access the result table of `SPI_execute` or another query-execution function across later calls.

SPI_exec

Name

`SPI_exec` — execute a read/write command

Synopsis

```
int SPI_exec(const char * command, long count)
```

Description

`SPI_exec` is the same as `SPI_execute`, with the latter's `read_only` parameter always taken as `false`.

Arguments

`const char * command`

string containing command to execute

`long count`

maximum number of rows to return, or `0` for no limit

Return Value

See `SPI_execute`.

SPI_execute_with_args

Name

SPI_execute_with_args — execute a command with out-of-line parameters

Synopsis

```
int SPI_execute_with_args(const char *command,
                          int nargs, Oid *argtypes,
                          Datum *values, const char *nulls,
                          bool read_only, long count)
```

Description

SPI_execute_with_args executes a command that might include references to externally supplied parameters. The command text refers to a parameter as $*n*, and the call specifies data types and values for each such symbol. read_only and count have the same interpretation as in SPI_execute.

The main advantage of this routine compared to SPI_execute is that data values can be inserted into the command without tedious quoting/escaping, and thus with much less risk of SQL-injection attacks.

Similar results can be achieved with SPI_prepare followed by SPI_execute_plan; however, when using this function the query plan is always customized to the specific parameter values provided. For one-time query execution, this function should be preferred. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

Arguments

const char * command

command string

int nargs

number of input parameters ($1, $2, etc.)

Oid * argtypes

an array of length nargs, containing the OIDs of the data types of the parameters

Datum * values

an array of length nargs, containing the actual parameter values

const char * nulls

an array of length nargs, describing which parameters are null

If nulls is NULL then SPI_execute_with_args assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value

in the corresponding `values` entry doesn't matter.) Note that `nulls` is not a text string, just an array: it does not need a `'\0'` terminator.

`bool read_only`

`true` for read-only execution

`long count`

maximum number of rows to return, or `0` for no limit

Return Value

The return value is the same as for `SPI_execute`.

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

SPI_prepare

Name

SPI_prepare — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare(const char * command, int nargs, Oid * argtypes)
```

Description

SPI_prepare creates and returns a prepared statement for the specified command, but doesn't execute the command. The prepared statement can later be executed repeatedly using SPI_execute_plan.

When the same or a similar command is to be executed repeatedly, it is generally advantageous to perform parse analysis only once, and might furthermore be advantageous to re-use an execution plan for the command. SPI_prepare converts a command string into a prepared statement that encapsulates the results of parse analysis. The prepared statement also provides a place for caching an execution plan if it is found that generating a custom plan for each execution is not helpful.

A prepared command can be generalized by writing parameters ($1, $2, etc.) in place of what would be constants in a normal command. The actual values of the parameters are then specified when SPI_execute_plan is called. This allows the prepared command to be used over a wider range of situations than would be possible without parameters.

The statement returned by SPI_prepare can be used only in the current invocation of the procedure, since SPI_finish frees memory allocated for such a statement. But the statement can be saved for longer using the functions SPI_keepplan or SPI_saveplan.

Arguments

`const char * command`

command string

`int nargs`

number of input parameters ($1, $2, etc.)

`Oid * argtypes`

pointer to an array containing the OIDs of the data types of the parameters

Return Value

SPI_prepare returns a non-null pointer to an SPIPlan, which is an opaque struct representing a prepared statement. On error, NULL will be returned, and SPI_result will be set to one of the same error codes used by SPI_execute, except that it is set to SPI_ERROR_ARGUMENT if command is NULL, or if nargs is less than 0, or if nargs is greater than 0 and argtypes is NULL.

Notes

If no parameters are defined, a generic plan will be created at the first use of `SPI_execute_plan`, and used for all subsequent executions as well. If there are parameters, the first few uses of `SPI_execute_plan` will generate custom plans that are specific to the supplied parameter values. After enough uses of the same prepared statement, `SPI_execute_plan` will build a generic plan, and if that is not too much more expensive than the custom plans, it will start using the generic plan instead of re-planning each time. If this default behavior is unsuitable, you can alter it by passing the `CURSOR_OPT_GENERIC_PLAN` or `CURSOR_OPT_CUSTOM_PLAN` flag to `SPI_prepare_cursor`, to force use of generic or custom plans respectively.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, PostgreSQL will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of search_path changes from one use to the next, the statement will be re-parsed using the new `search_path`. (This latter behavior is new as of PostgreSQL 9.3.) See PREPARE for more information about the behavior of prepared statements.

This function should only be called from a connected procedure.

`SPIPlanPtr` is declared as a pointer to an opaque struct type in `spi.h`. It is unwise to try to access its contents directly, as that makes your code much more likely to break in future revisions of PostgreSQL.

The name `SPIPlanPtr` is somewhat historical, since the data structure no longer necessarily contains an execution plan.

SPI_prepare_cursor

Name

SPI_prepare_cursor — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare_cursor(const char * command, int nargs,
                              Oid * argtypes, int cursorOptions)
```

Description

SPI_prepare_cursor is identical to SPI_prepare, except that it also allows specification of the planner's "cursor options" parameter. This is a bit mask having the values shown in nodes/parsenodes.h for the options field of DeclareCursorStmt. SPI_prepare always takes the cursor options as zero.

Arguments

const char * command

command string

int nargs

number of input parameters ($1, $2, etc.)

Oid * argtypes

pointer to an array containing the OIDs of the data types of the parameters

int cursorOptions

integer bit mask of cursor options; zero produces default behavior

Return Value

SPI_prepare_cursor has the same return conventions as SPI_prepare.

Notes

Useful bits to set in cursorOptions include CURSOR_OPT_SCROLL, CURSOR_OPT_NO_SCROLL, CURSOR_OPT_FAST_PLAN, CURSOR_OPT_GENERIC_PLAN, and CURSOR_OPT_CUSTOM_PLAN. Note in particular that CURSOR_OPT_HOLD is ignored.

SPI_prepare_params

Name

SPI_prepare_params — prepare a statement, without executing it yet

Synopsis

```
SPIPlanPtr SPI_prepare_params(const char * command,
                              ParserSetupHook parserSetup,
                              void * parserSetupArg,
                              int cursorOptions)
```

Description

SPI_prepare_params creates and returns a prepared statement for the specified command, but doesn't execute the command. This function is equivalent to SPI_prepare_cursor, with the addition that the caller can specify parser hook functions to control the parsing of external parameter references.

Arguments

`const char * command`

command string

`ParserSetupHook parserSetup`

Parser hook setup function

`void * parserSetupArg`

pass-through argument for parserSetup

`int cursorOptions`

integer bit mask of cursor options; zero produces default behavior

Return Value

SPI_prepare_params has the same return conventions as SPI_prepare.

SPI_getargcount

Name

`SPI_getargcount` — return the number of arguments needed by a statement prepared by `SPI_prepare`

Synopsis

```
int SPI_getargcount(SPIPlanPtr plan)
```

Description

`SPI_getargcount` returns the number of arguments needed to execute a statement prepared by `SPI_prepare`.

Arguments

`SPIPlanPtr plan`

prepared statement (returned by `SPI_prepare`)

Return Value

The count of expected arguments for the `plan`. If the `plan` is `NULL` or invalid, `SPI_result` is set to `SPI_ERROR_ARGUMENT` and -1 is returned.

SPI_getargtypeid

Name

SPI_getargtypeid — return the data type OID for an argument of a statement prepared by SPI_prepare

Synopsis

```
Oid SPI_getargtypeid(SPIPlanPtr plan, int argIndex)
```

Description

SPI_getargtypeid returns the OID representing the type for the argIndex'th argument of a statement prepared by SPI_prepare. First argument is at index zero.

Arguments

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

int argIndex

zero based index of the argument

Return Value

The type OID of the argument at the given index. If the plan is NULL or invalid, or argIndex is less than 0 or not less than the number of arguments declared for the plan, SPI_result is set to SPI_ERROR_ARGUMENT and InvalidOid is returned.

SPI_is_cursor_plan

Name

SPI_is_cursor_plan — return true if a statement prepared by SPI_prepare can be used with SPI_cursor_open

Synopsis

```
bool SPI_is_cursor_plan(SPIPlanPtr plan)
```

Description

SPI_is_cursor_plan returns true if a statement prepared by SPI_prepare can be passed as an argument to SPI_cursor_open, or false if that is not the case. The criteria are that the plan represents one single command and that this command returns tuples to the caller; for example, SELECT is allowed unless it contains an INTO clause, and UPDATE is allowed only if it contains a RETURNING clause.

Arguments

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

Return Value

true or false to indicate if the plan can produce a cursor or not, with SPI_result set to zero. If it is not possible to determine the answer (for example, if the plan is NULL or invalid, or if called when not connected to SPI), then SPI_result is set to a suitable error code and false is returned.

SPI_execute_plan

Name

SPI_execute_plan — execute a statement prepared by SPI_prepare

Synopsis

```
int SPI_execute_plan(SPIPlanPtr plan, Datum * values, const char * nulls,
                     bool read_only, long count)
```

Description

SPI_execute_plan executes a statement prepared by SPI_prepare or one of its siblings. read_only and count have the same interpretation as in SPI_execute.

Arguments

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

Datum * values

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char * nulls

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If nulls is NULL then SPI_execute_plan assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a '\0' terminator.

bool read_only

true for read-only execution

long count

maximum number of rows to return, or 0 for no limit

Return Value

The return value is the same as for `SPI_execute`, with the following additional possible error (negative) results:

`SPI_ERROR_ARGUMENT`

if `plan` is `NULL` or invalid, or `count` is less than 0

`SPI_ERROR_PARAM`

if `values` is `NULL` and `plan` was prepared with some parameters

`SPI_processed` and `SPI_tuptable` are set as in `SPI_execute` if successful.

SPI_execute_plan_with_paramlist

Name

SPI_execute_plan_with_paramlist — execute a statement prepared by SPI_prepare

Synopsis

```
int SPI_execute_plan_with_paramlist(SPIPlanPtr plan,
                                    ParamListInfo params,
                                    bool read_only,
                                    long count)
```

Description

SPI_execute_plan_with_paramlist executes a statement prepared by SPI_prepare. This function is equivalent to SPI_execute_plan except that information about the parameter values to be passed to the query is presented differently. The ParamListInfo representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in ParamListInfo.

Arguments

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

ParamListInfo params

data structure containing parameter types and values; NULL if none

bool read_only

true for read-only execution

long count

maximum number of rows to return, or 0 for no limit

Return Value

The return value is the same as for SPI_execute_plan.

SPI_processed and SPI_tuptable are set as in SPI_execute_plan if successful.

SPI_execp

Name

SPI_execp — execute a statement in read/write mode

Synopsis

```
int SPI_execp(SPIPlanPtr plan, Datum * values, const char * nulls, long count)
```

Description

SPI_execp is the same as SPI_execute_plan, with the latter's read_only parameter always taken as false.

Arguments

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

Datum * values

An array of actual parameter values. Must have same length as the statement's number of arguments.

const char * nulls

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If nulls is NULL then SPI_execp assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is non-null, or 'n' if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a '\0' terminator.

long count

maximum number of rows to return, or 0 for no limit

Return Value

See SPI_execute_plan.

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

SPI_cursor_open

Name

SPI_cursor_open — set up a cursor using a statement created with SPI_prepare

Synopsis

```
Portal SPI_cursor_open(const char * name, SPIPlanPtr plan,
                       Datum * values, const char * nulls,
                       bool read_only)
```

Description

SPI_cursor_open sets up a cursor (internally, a portal) that will execute a statement prepared by SPI_prepare. The parameters have the same meanings as the corresponding parameters to SPI_execute_plan.

Using a cursor instead of executing the statement directly has two benefits. First, the result rows can be retrieved a few at a time, avoiding memory overrun for queries that return many rows. Second, a portal can outlive the current procedure (it can, in fact, live to the end of the current transaction). Returning the portal name to the procedure's caller provides a way of returning a row set as result.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

`const char * name`

name for portal, or NULL to let the system select a name

`SPIPlanPtr plan`

prepared statement (returned by SPI_prepare)

`Datum * values`

An array of actual parameter values. Must have same length as the statement's number of arguments.

`const char * nulls`

An array describing which parameters are null. Must have same length as the statement's number of arguments.

If nulls is NULL then SPI_cursor_open assumes that no parameters are null. Otherwise, each entry of the nulls array should be `' '` if the corresponding parameter value is non-null, or `'n'` if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a `'\0'` terminator.

`bool read_only`

`true` for read-only execution

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via `elog`.

SPI_cursor_open_with_args

Name

SPI_cursor_open_with_args — set up a cursor using a query and parameters

Synopsis

```
Portal SPI_cursor_open_with_args(const char *name,
                                 const char *command,
                                 int nargs, Oid *argtypes,
                                 Datum *values, const char *nulls,
                                 bool read_only, int cursorOptions)
```

Description

SPI_cursor_open_with_args sets up a cursor (internally, a portal) that will execute the specified query. Most of the parameters have the same meanings as the corresponding parameters to SPI_prepare_cursor and SPI_cursor_open.

For one-time query execution, this function should be preferred over SPI_prepare_cursor followed by SPI_cursor_open. If the same command is to be executed with many different parameters, either method might be faster, depending on the cost of re-planning versus the benefit of custom plans.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

const char * name

name for portal, or NULL to let the system select a name

const char * command

command string

int nargs

number of input parameters ($1, $2, etc.)

Oid * argtypes

an array of length nargs, containing the OIDs of the data types of the parameters

Datum * values

an array of length nargs, containing the actual parameter values

const char * nulls

an array of length nargs, describing which parameters are null

If nulls is NULL then SPI_cursor_open_with_args assumes that no parameters are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding parameter value is

non-null, or `'n'` if the corresponding parameter value is null. (In the latter case, the actual value in the corresponding `values` entry doesn't matter.) Note that `nulls` is not a text string, just an array: it does not need a `'\0'` terminator.

`bool read_only`

`true` for read-only execution

`int cursorOptions`

integer bit mask of cursor options; zero produces default behavior

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via `elog`.

SPI_cursor_open_with_paramlist

Name

SPI_cursor_open_with_paramlist — set up a cursor using parameters

Synopsis

```
Portal SPI_cursor_open_with_paramlist(const char *name,
                                      SPIPlanPtr plan,
                                      ParamListInfo params,
                                      bool read_only)
```

Description

SPI_cursor_open_with_paramlist sets up a cursor (internally, a portal) that will execute a statement prepared by SPI_prepare. This function is equivalent to SPI_cursor_open except that information about the parameter values to be passed to the query is presented differently. The ParamListInfo representation can be convenient for passing down values that are already available in that format. It also supports use of dynamic parameter sets via hook functions specified in ParamListInfo.

The passed-in parameter data will be copied into the cursor's portal, so it can be freed while the cursor still exists.

Arguments

const char * name

name for portal, or NULL to let the system select a name

SPIPlanPtr plan

prepared statement (returned by SPI_prepare)

ParamListInfo params

data structure containing parameter types and values; NULL if none

bool read_only

true for read-only execution

Return Value

Pointer to portal containing the cursor. Note there is no error return convention; any error will be reported via elog.

SPI_cursor_find

Name

`SPI_cursor_find` — find an existing cursor by name

Synopsis

```
Portal SPI_cursor_find(const char * name)
```

Description

`SPI_cursor_find` finds an existing portal by name. This is primarily useful to resolve a cursor name returned as text by some other function.

Arguments

`const char * name`

name of the portal

Return Value

pointer to the portal with the specified name, or `NULL` if none was found

SPI_cursor_fetch

Name

SPI_cursor_fetch — fetch some rows from a cursor

Synopsis

```
void SPI_cursor_fetch(Portal portal, bool forward, long count)
```

Description

SPI_cursor_fetch fetches some rows from a cursor. This is equivalent to a subset of the SQL command FETCH (see SPI_scroll_cursor_fetch for more functionality).

Arguments

Portal portal

portal containing the cursor

bool forward

true for fetch forward, false for fetch backward

long count

maximum number of rows to fetch

Return Value

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

Notes

Fetching backward may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_cursor_move

Name

`SPI_cursor_move` — move a cursor

Synopsis

```
void SPI_cursor_move(Portal portal, bool forward, long count)
```

Description

`SPI_cursor_move` skips over some number of rows in a cursor. This is equivalent to a subset of the SQL command `MOVE` (see `SPI_scroll_cursor_move` for more functionality).

Arguments

`Portal portal`

portal containing the cursor

`bool forward`

true for move forward, false for move backward

`long count`

maximum number of rows to move

Notes

Moving backward may fail if the cursor's plan was not created with the `CURSOR_OPT_SCROLL` option.

SPI_scroll_cursor_fetch

Name

SPI_scroll_cursor_fetch — fetch some rows from a cursor

Synopsis

```
void SPI_scroll_cursor_fetch(Portal portal, FetchDirection direction,
                             long count)
```

Description

SPI_scroll_cursor_fetch fetches some rows from a cursor. This is equivalent to the SQL command FETCH.

Arguments

Portal portal

portal containing the cursor

FetchDirection direction

one of FETCH_FORWARD, FETCH_BACKWARD, FETCH_ABSOLUTE or FETCH_RELATIVE

long count

number of rows to fetch for FETCH_FORWARD or FETCH_BACKWARD; absolute row number to fetch for FETCH_ABSOLUTE; or relative row number to fetch for FETCH_RELATIVE

Return Value

SPI_processed and SPI_tuptable are set as in SPI_execute if successful.

Notes

See the SQL FETCH command for details of the interpretation of the direction and count parameters.

Direction values other than FETCH_FORWARD may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_scroll_cursor_move

Name

SPI_scroll_cursor_move — move a cursor

Synopsis

```
void SPI_scroll_cursor_move(Portal portal, FetchDirection direction,
                            long count)
```

Description

SPI_scroll_cursor_move skips over some number of rows in a cursor. This is equivalent to the SQL command MOVE.

Arguments

Portal portal

portal containing the cursor

FetchDirection direction

one of FETCH_FORWARD, FETCH_BACKWARD, FETCH_ABSOLUTE or FETCH_RELATIVE

long count

number of rows to move for FETCH_FORWARD or FETCH_BACKWARD; absolute row number to move to for FETCH_ABSOLUTE; or relative row number to move to for FETCH_RELATIVE

Return Value

SPI_processed is set as in SPI_execute if successful. SPI_tuptable is set to NULL, since no rows are returned by this function.

Notes

See the SQL FETCH command for details of the interpretation of the direction and count parameters.

Direction values other than FETCH_FORWARD may fail if the cursor's plan was not created with the CURSOR_OPT_SCROLL option.

SPI_cursor_close

Name

`SPI_cursor_close` — close a cursor

Synopsis

```
void SPI_cursor_close(Portal portal)
```

Description

`SPI_cursor_close` closes a previously created cursor and releases its portal storage.

All open cursors are closed automatically at the end of a transaction. `SPI_cursor_close` need only be invoked if it is desirable to release resources sooner.

Arguments

`Portal portal`

portal containing the cursor

SPI_keepplan

Name

SPI_keepplan — save a prepared statement

Synopsis

```
int SPI_keepplan(SPIPlanPtr plan)
```

Description

SPI_keepplan saves a passed statement (prepared by SPI_prepare) so that it will not be freed by SPI_finish nor by the transaction manager. This gives you the ability to reuse prepared statements in the subsequent invocations of your procedure in the current session.

Arguments

SPIPlanPtr plan

the prepared statement to be saved

Return Value

0 on success; SPI_ERROR_ARGUMENT if plan is NULL or invalid

Notes

The passed-in statement is relocated to permanent storage by means of pointer adjustment (no data copying is required). If you later wish to delete it, use SPI_freeplan on it.

SPI_saveplan

Name

SPI_saveplan — save a prepared statement

Synopsis

```
SPIPlanPtr SPI_saveplan(SPIPlanPtr plan)
```

Description

SPI_saveplan copies a passed statement (prepared by SPI_prepare) into memory that will not be freed by SPI_finish nor by the transaction manager, and returns a pointer to the copied statement. This gives you the ability to reuse prepared statements in the subsequent invocations of your procedure in the current session.

Arguments

SPIPlanPtr plan

the prepared statement to be saved

Return Value

Pointer to the copied statement; or NULL if unsuccessful. On error, SPI_result is set thus:

SPI_ERROR_ARGUMENT

if plan is NULL or invalid

SPI_ERROR_UNCONNECTED

if called from an unconnected procedure

Notes

The originally passed-in statement is not freed, so you might wish to do SPI_freeplan on it to avoid leaking memory until SPI_finish.

In most cases, SPI_keepplan is preferred to this function, since it accomplishes largely the same result without needing to physically copy the prepared statement's data structures.

44.2. Interface Support Functions

The functions described here provide an interface for extracting information from result sets returned by `SPI_execute` and other SPI functions.

All functions described in this section can be used by both connected and unconnected procedures.

SPI_fname

Name

`SPI_fname` — determine the column name for the specified column number

Synopsis

```
char * SPI_fname(TupleDesc rowdesc, int colnumber)
```

Description

`SPI_fname` returns a copy of the column name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The column name; `NULL` if `colnumber` is out of range. `SPI_result` set to `SPI_ERROR_NOATTRIBUTE` on error.

SPI_fnumber

Name

`SPI_fnumber` — determine the column number for the specified column name

Synopsis

```
int SPI_fnumber(TupleDesc rowdesc, const char * colname)
```

Description

`SPI_fnumber` returns the column number for the column with the specified name.

If `colname` refers to a system column (e.g., `oid`) then the appropriate negative column number will be returned. The caller should be careful to test the return value for exact equality to `SPI_ERROR_NOATTRIBUTE` to detect an error; testing the result for less than or equal to 0 is not correct unless system columns should be rejected.

Arguments

`TupleDesc rowdesc`

input row description

`const char * colname`

column name

Return Value

Column number (count starts at 1), or `SPI_ERROR_NOATTRIBUTE` if the named column was not found.

SPI_getvalue

Name

`SPI_getvalue` — return the string value of the specified column

Synopsis

```
char * SPI_getvalue(HeapTuple row, TupleDesc rowdesc, int colnumber)
```

Description

`SPI_getvalue` returns the string representation of the value of the specified column.

The result is returned in memory allocated using `palloc`. (You can use `pfree` to release the memory when you don't need it anymore.)

Arguments

`HeapTuple row`

input row to be examined

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

Column value, or `NULL` if the column is null, `colnumber` is out of range (`SPI_result` is set to `SPI_ERROR_NOATTRIBUTE`), or no output function is available (`SPI_result` is set to `SPI_ERROR_NOOUTFUNC`).

SPI_getbinval

Name

`SPI_getbinval` — return the binary value of the specified column

Synopsis

```
Datum SPI_getbinval(HeapTuple row, TupleDesc rowdesc, int colnumber,
                    bool * isnull)
```

Description

`SPI_getbinval` returns the value of the specified column in the internal form (as type `Datum`).

This function does not allocate new space for the datum. In the case of a pass-by-reference data type, the return value will be a pointer into the passed row.

Arguments

`HeapTuple row`

input row to be examined

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

`bool * isnull`

flag for a null value in the column

Return Value

The binary value of the column is returned. The variable pointed to by `isnull` is set to true if the column is null, else to false.

`SPI_result` is set to `SPI_ERROR_NOATTRIBUTE` on error.

SPI_gettype

Name

`SPI_gettype` — return the data type name of the specified column

Synopsis

```
char * SPI_gettype(TupleDesc rowdesc, int colnumber)
```

Description

`SPI_gettype` returns a copy of the data type name of the specified column. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The data type name of the specified column, or `NULL` on error. `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE` on error.

SPI_gettypeid

Name

`SPI_gettypeid` — return the data type OID of the specified column

Synopsis

```
Oid SPI_gettypeid(TupleDesc rowdesc, int colnumber)
```

Description

`SPI_gettypeid` returns the OID of the data type of the specified column.

Arguments

`TupleDesc rowdesc`

input row description

`int colnumber`

column number (count starts at 1)

Return Value

The OID of the data type of the specified column or `InvalidOid` on error. On error, `SPI_result` is set to `SPI_ERROR_NOATTRIBUTE`.

SPI_getrelname

Name

`SPI_getrelname` — return the name of the specified relation

Synopsis

```
char * SPI_getrelname(Relation rel)
```

Description

`SPI_getrelname` returns a copy of the name of the specified relation. (You can use `pfree` to release the copy of the name when you don't need it anymore.)

Arguments

`Relation rel`

input relation

Return Value

The name of the specified relation.

SPI_getnspname

Name

`SPI_getnspname` — return the namespace of the specified relation

Synopsis

```
char * SPI_getnspname(Relation rel)
```

Description

`SPI_getnspname` returns a copy of the name of the namespace that the specified `Relation` belongs to. This is equivalent to the relation's schema. You should `pfree` the return value of this function when you are finished with it.

Arguments

`Relation rel`

input relation

Return Value

The name of the specified relation's namespace.

44.3. Memory Management

PostgreSQL allocates memory within *memory contexts*, which provide a convenient method of managing allocations made in many different places that need to live for differing amounts of time. Destroying a context releases all the memory that was allocated in it. Thus, it is not necessary to keep track of individual objects to avoid memory leaks; instead only a relatively small number of contexts have to be managed. `palloc` and related functions allocate memory from the "current" context.

`SPI_connect` creates a new memory context and makes it current. `SPI_finish` restores the previous current memory context and destroys the context created by `SPI_connect`. These actions ensure that transient memory allocations made inside your procedure are reclaimed at procedure exit, avoiding memory leakage.

However, if your procedure needs to return an object in allocated memory (such as a value of a pass-by-reference data type), you cannot allocate that memory using `palloc`, at least not while you are connected to SPI. If you try, the object will be deallocated by `SPI_finish`, and your procedure will not work reliably. To solve this problem, use `SPI_palloc` to allocate memory for your return object. `SPI_palloc` allocates memory in the "upper executor context", that is, the memory context that was current when `SPI_connect` was called, which is precisely the right context for a value returned from your procedure.

If `SPI_palloc` is called while the procedure is not connected to SPI, then it acts the same as a normal `palloc`. Before a procedure connects to the SPI manager, the current memory context is the upper executor context, so all allocations made by the procedure via `palloc` or by SPI utility functions are made in this context.

When `SPI_connect` is called, the private context of the procedure, which is created by `SPI_connect`, is made the current context. All allocations made by `palloc`, `repalloc`, or SPI utility functions (except for `SPI_copytuple`, `SPI_returntuple`, `SPI_modifytuple`, and `SPI_palloc`) are made in this context. When a procedure disconnects from the SPI manager (via `SPI_finish`) the current context is restored to the upper executor context, and all allocations made in the procedure memory context are freed and cannot be used any more.

All functions described in this section can be used by both connected and unconnected procedures. In an unconnected procedure, they act the same as the underlying ordinary server functions (`palloc`, etc.).

SPI_palloc

Name

`SPI_palloc` — allocate memory in the upper executor context

Synopsis

```
void * SPI_palloc(Size size)
```

Description

`SPI_palloc` allocates memory in the upper executor context.

Arguments

`Size size`

size in bytes of storage to allocate

Return Value

pointer to new storage space of the specified size

SPI_repalloc

Name

`SPI_repalloc` — reallocate memory in the upper executor context

Synopsis

```
void * SPI_repalloc(void * pointer, Size size)
```

Description

`SPI_repalloc` changes the size of a memory segment previously allocated using `SPI_palloc`.

This function is no longer different from plain `repalloc`. It's kept just for backward compatibility of existing code.

Arguments

`void * pointer`

pointer to existing storage to change

`Size size`

size in bytes of storage to allocate

Return Value

pointer to new storage space of specified size with the contents copied from the existing area

SPI_pfree

Name

`SPI_pfree` — free memory in the upper executor context

Synopsis

```
void SPI_pfree(void * pointer)
```

Description

`SPI_pfree` frees memory previously allocated using `SPI_palloc` or `SPI_repalloc`.

This function is no longer different from plain `pfree`. It's kept just for backward compatibility of existing code.

Arguments

`void * pointer`

pointer to existing storage to free

SPI_copytuple

Name

`SPI_copytuple` — make a copy of a row in the upper executor context

Synopsis

```
HeapTuple SPI_copytuple(HeapTuple row)
```

Description

`SPI_copytuple` makes a copy of a row in the upper executor context. This is normally used to return a modified row from a trigger. In a function declared to return a composite type, use `SPI_returntuple` instead.

Arguments

`HeapTuple row`

row to be copied

Return Value

the copied row; `NULL` only if `tuple` is `NULL`

SPI_returntuple

Name

`SPI_returntuple` — prepare to return a tuple as a Datum

Synopsis

```
HeapTupleHeader SPI_returntuple(HeapTuple row, TupleDesc rowdesc)
```

Description

`SPI_returntuple` makes a copy of a row in the upper executor context, returning it in the form of a row type `Datum`. The returned pointer need only be converted to `Datum` via `PointerGetDatum` before returning.

Note that this should be used for functions that are declared to return composite types. It is not used for triggers; use `SPI_copytuple` for returning a modified row in a trigger.

Arguments

`HeapTuple row`

row to be copied

`TupleDesc rowdesc`

descriptor for row (pass the same descriptor each time for most effective caching)

Return Value

`HeapTupleHeader` pointing to copied row; `NULL` only if `row` or `rowdesc` is `NULL`

SPI_modifytuple

Name

SPI_modifytuple — create a row by replacing selected fields of a given row

Synopsis

```
HeapTuple SPI_modifytuple(Relation rel, HeapTuple row, int ncols,
                          int * colnum, Datum * values, const char * nulls)
```

Description

SPI_modifytuple creates a new row by substituting new values for selected columns, copying the original row's columns at other positions. The input row is not modified.

Arguments

Relation rel

Used only as the source of the row descriptor for the row. (Passing a relation rather than a row descriptor is a misfeature.)

HeapTuple row

row to be modified

int ncols

number of columns to be changed

int * colnum

an array of length ncols, containing the numbers of the columns that are to be changed (column numbers start at 1)

Datum * values

an array of length ncols, containing the new values for the specified columns

const char * nulls

an array of length ncols, describing which new values are null

If nulls is NULL then SPI_modifytuple assumes that no new values are null. Otherwise, each entry of the nulls array should be ' ' if the corresponding new value is non-null, or 'n' if the corresponding new value is null. (In the latter case, the actual value in the corresponding values entry doesn't matter.) Note that nulls is not a text string, just an array: it does not need a '\0' terminator.

Return Value

new row with modifications, allocated in the upper executor context; NULL only if row is NULL

On error, `SPI_result` is set as follows:

`SPI_ERROR_ARGUMENT`

if `rel` is `NULL`, or if `row` is `NULL`, or if `ncols` is less than or equal to 0, or if `colnum` is `NULL`, or if `values` is `NULL`.

`SPI_ERROR_NOATTRIBUTE`

if `colnum` contains an invalid column number (less than or equal to 0 or greater than the number of column in `row`)

SPI_freetuple

Name

`SPI_freetuple` — free a row allocated in the upper executor context

Synopsis

```
void SPI_freetuple(HeapTuple row)
```

Description

`SPI_freetuple` frees a row previously allocated in the upper executor context.

This function is no longer different from plain `heap_freetuple`. It's kept just for backward compatibility of existing code.

Arguments

`HeapTuple row`

row to free

SPI_freetuptable

Name

`SPI_freetuptable` — free a row set created by `SPI_execute` or a similar function

Synopsis

```
void SPI_freetuptable(SPITupleTable * tuptable)
```

Description

`SPI_freetuptable` frees a row set created by a prior SPI command execution function, such as `SPI_execute`. Therefore, this function is often called with the global variable `SPI_tuptable` as argument.

This function is useful if a SPI procedure needs to execute multiple commands and does not want to keep the results of earlier commands around until it ends. Note that any unfreed row sets will be freed anyway at `SPI_finish`. Also, if a subtransaction is started and then aborted within execution of a SPI procedure, SPI automatically frees any row sets created while the subtransaction was running.

Beginning in PostgreSQL 9.3, `SPI_freetuptable` contains guard logic to protect against duplicate deletion requests for the same row set. In previous releases, duplicate deletions would lead to crashes.

Arguments

`SPITupleTable * tuptable`

pointer to row set to free, or NULL to do nothing

SPI_freeplan

Name

`SPI_freeplan` — free a previously saved prepared statement

Synopsis

```
int SPI_freeplan(SPIPlanPtr plan)
```

Description

`SPI_freeplan` releases a prepared statement previously returned by `SPI_prepare` or saved by `SPI_keepplan` or `SPI_saveplan`.

Arguments

`SPIPlanPtr plan`

pointer to statement to free

Return Value

0 on success; `SPI_ERROR_ARGUMENT` if `plan` is `NULL` or invalid

44.4. Visibility of Data Changes

The following rules govern the visibility of data changes in functions that use SPI (or any other C function):

- During the execution of an SQL command, any data changes made by the command are invisible to the command itself. For example, in:

  ```
  INSERT INTO a SELECT * FROM a;
  ```
  the inserted rows are invisible to the `SELECT` part.
- Changes made by a command C are visible to all commands that are started after C, no matter whether they are started inside C (during the execution of C) or after C is done.
- Commands executed via SPI inside a function called by an SQL command (either an ordinary function or a trigger) follow one or the other of the above rules depending on the read/write flag passed to SPI. Commands executed in read-only mode follow the first rule: they cannot see changes of the calling command. Commands executed in read-write mode follow the second rule: they can see all changes made so far.
- All standard procedural languages set the SPI read-write mode depending on the volatility attribute of the function. Commands of `STABLE` and `IMMUTABLE` functions are done in read-only mode, while commands of `VOLATILE` functions are done in read-write mode. While authors of C functions are able to violate this convention, it's unlikely to be a good idea to do so.

The next section contains an example that illustrates the application of these rules.

44.5. Examples

This section contains a very simple example of SPI usage. The procedure `execq` takes an SQL command as its first argument and a row count as its second, executes the command using `SPI_exec` and returns the number of rows that were processed by the command. You can find more complex examples for SPI in the source tree in `src/test/regress/regress.c` and in the spi module.

```
#include "postgres.h"

#include "executor/spi.h"
#include "utils/builtins.h"

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif

int execq(text *sql, int cnt);

int
execq(text *sql, int cnt)
{
    char *command;
    int ret;
    int proc;

    /* Convert given text object to a C string */
```

```
    command = text_to_cstring(sql);

    SPI_connect();

    ret = SPI_exec(command, cnt);

    proc = SPI_processed;
    /*
     * If some rows were fetched, print them via elog(INFO).
     */
    if (ret > 0 && SPI_tuptable != NULL)
    {
        TupleDesc tupdesc = SPI_tuptable->tupdesc;
        SPITupleTable *tuptable = SPI_tuptable;
        char buf[8192];
        int i, j;

        for (j = 0; j < proc; j++)
        {
            HeapTuple tuple = tuptable->vals[j];

            for (i = 1, buf[0] = 0; i <= tupdesc->natts; i++)
                snprintf(buf + strlen (buf), sizeof(buf) - strlen(buf), " %s%s",
                        SPI_getvalue(tuple, tupdesc, i),
                        (i == tupdesc->natts) ? " " : " |");
            elog(INFO, "EXECQ: %s", buf);
        }
    }

    SPI_finish();
    pfree(command);

    return (proc);
}
```

(This function uses call convention version 0, to make the example easier to understand. In real applications you should use the new version 1 interface.)

This is how you declare the function after having compiled it into a shared library (details are in Section 35.9.6.):

```
CREATE FUNCTION execq(text, integer) RETURNS integer
    AS 'filename'
    LANGUAGE C;
```

Here is a sample session:

```
=> SELECT execq('CREATE TABLE a (x integer)', 0);
 execq
-------
     0
(1 row)

=> INSERT INTO a VALUES (execq('INSERT INTO a VALUES (0)', 0));
INSERT 0 1
=> SELECT execq('SELECT * FROM a', 0);
```

```
INFO:  EXECQ:  0    -- inserted by execq
INFO:  EXECQ:  1    -- returned by execq and inserted by upper INSERT

 execq
-------
     2
(1 row)

=> SELECT execq('INSERT INTO a SELECT x + 2 FROM a', 1);
 execq
-------
     1
(1 row)

=> SELECT execq('SELECT * FROM a', 10);
INFO:  EXECQ:  0
INFO:  EXECQ:  1
INFO:  EXECQ:  2    -- 0 + 2, only one row inserted - as specified

 execq
-------
     3              -- 10 is the max value only, 3 is the real number of rows
(1 row)

=> DELETE FROM a;
DELETE 3
=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INSERT 0 1
=> SELECT * FROM a;
 x
---
 1                  -- no rows in a (0) + 1
(1 row)

=> INSERT INTO a VALUES (execq('SELECT * FROM a', 0) + 1);
INFO:  EXECQ:  1
INSERT 0 1
=> SELECT * FROM a;
 x
---
 1
 2                  -- there was one row in a + 1
(2 rows)

-- This demonstrates the data changes visibility rule:

=> INSERT INTO a SELECT execq('SELECT * FROM a', 0) * x FROM a;
INFO:  EXECQ:  1
INFO:  EXECQ:  2
INFO:  EXECQ:  1
INFO:  EXECQ:  2
INFO:  EXECQ:  2
INSERT 0 2
=> SELECT * FROM a;
 x
---
 1
```

```
 2
 2                  -- 2 rows * 1 (x in first row)
 6                  -- 3 rows (2 + 1 just inserted) * 2 (x in second row)
(4 rows)               ^^^^^^
                       rows visible to execq() in different invocations
```

Chapter 45. Background Worker Processes

PostgreSQL can be extended to run user-supplied code in separate processes. Such processes are started, stopped and monitored by `postgres`, which permits them to have a lifetime closely linked to the server's status. These processes have the option to attach to PostgreSQL's shared memory area and to connect to databases internally; they can also run multiple transactions serially, just like a regular client-connected server process. Also, by linking to libpq they can connect to the server and behave like a regular client application.

> **Warning**
>
> There are considerable robustness and security risks in using background worker processes because, being written in the `C` language, they have unrestricted access to data. Administrators wishing to enable modules that include background worker process should exercise extreme caution. Only carefully audited modules should be permitted to run background worker processes.

Background workers can be initialized at the time that PostgreSQL is started by including the module name in `shared_preload_libraries`. A module wishing to run a background worker can register it by calling `RegisterBackgroundWorker(BackgroundWorker *worker)` from its `_PG_init()`. Background workers can also be started after the system is up and running by calling the function `RegisterDynamicBackgroundWorker(BackgroundWorker *worker, BackgroundWorkerHandle **handle)`. Unlike `RegisterBackgroundWorker`, which can only be called from within the postmaster, `RegisterDynamicBackgroundWorker` must be called from a regular backend.

The structure `BackgroundWorker` is defined thus:

```
typedef void (*bgworker_main_type)(Datum main_arg);
typedef struct BackgroundWorker
{
    char        bgw_name[BGW_MAXLEN];
    int         bgw_flags;
    BgWorkerStartTime bgw_start_time;
    int         bgw_restart_time;       /* in seconds, or BGW_NEVER_RESTART */
    bgworker_main_type bgw_main;
    char        bgw_library_name[BGW_MAXLEN];   /* only if bgw_main is NULL */
    char        bgw_function_name[BGW_MAXLEN];  /* only if bgw_main is NULL */
    Datum       bgw_main_arg;
    int         bgw_notify_pid;
} BackgroundWorker;
```

`bgw_name` is a string to be used in log messages, process listings and similar contexts.

`bgw_flags` is a bitwise-or'd bit mask indicating the capabilities that the module wants. Possible values are `BGWORKER_SHMEM_ACCESS` (requesting shared memory access) and `BGWORKER_BACKEND_DATABASE_CONNECTION` (requesting the ability to establish a database connection, through which it can later run transactions and queries). A background worker using `BGWORKER_BACKEND_DATABASE_CONNECTION` to connect to a database must also attach shared memory using `BGWORKER_SHMEM_ACCESS`, or worker start-up will fail.

`bgw_start_time` is the server state during which `postgres` should start the process; it can be one of `BgWorkerStart_PostmasterStart` (start as soon as `postgres` itself has finished

its own initialization; processes requesting this are not eligible for database connections), BgWorkerStart_ConsistentState (start as soon as a consistent state has been reached in a hot standby, allowing processes to connect to databases and run read-only queries), and BgWorkerStart_RecoveryFinished (start as soon as the system has entered normal read-write state). Note the last two values are equivalent in a server that's not a hot standby. Note that this setting only indicates when the processes are to be started; they do not stop when a different state is reached.

bgw_restart_time is the interval, in seconds, that postgres should wait before restarting the process, in case it crashes. It can be any positive value, or BGW_NEVER_RESTART, indicating not to restart the process in case of a crash.

bgw_main is a pointer to the function to run when the process is started. This function must take a single argument of type Datum and return void. bgw_main_arg will be passed to it as its only argument. Note that the global variable MyBgworkerEntry points to a copy of the BackgroundWorker structure passed at registration time. bgw_main may be NULL; in that case, bgw_library_name and bgw_function_name will be used to determine the entry point. This is useful for background workers launched after postmaster startup, where the postmaster does not have the requisite library loaded.

bgw_library_name is the name of a library in which the initial entry point for the background worker should be sought. It is ignored unless bgw_main is NULL. But if bgw_main is NULL, then the named library will be dynamically loaded by the worker process and bgw_function_name will be used to identify the function to be called.

bgw_function_name is the name of a function in a dynamically loaded library which should be used as the initial entry point for a new background worker. It is ignored unless bgw_main is NULL.

bgw_notify_pid is the PID of a PostgreSQL backend process to which the postmaster should send SIGUSR1 when the process is started or exits. It should be 0 for workers registered at postmaster startup time, or when the backend registering the worker does not wish to wait for the worker to start up. Otherwise, it should be initialized to MyProcPid.

Once running, the process can connect to a database by calling BackgroundWorkerInitializeConnection(char *dbname, char *username). This allows the process to run transactions and queries using the SPI interface. If dbname is NULL, the session is not connected to any particular database, but shared catalogs can be accessed. If username is NULL, the process will run as the superuser created during initdb. BackgroundWorkerInitializeConnection can only be called once per background process, it is not possible to switch databases.

Signals are initially blocked when control reaches the bgw_main function, and must be unblocked by it; this is to allow the process to customize its signal handlers, if necessary. Signals can be unblocked in the new process by calling BackgroundWorkerUnblockSignals and blocked by calling BackgroundWorkerBlockSignals.

If bgw_restart_time for a background worker is configured as BGW_NEVER_RESTART, or if it exits with an exit code of 0 or is terminated by TerminateBackgroundWorker, it will be automatically unregistered by the postmaster on exit. Otherwise, it will be restarted after the time period configured via bgw_restart_time, or immediately if the postmaster reinitializes the cluster due to a backend failure. Backends which need to suspend execution only temporarily should use an interruptible sleep rather than exiting; this can be achieved by calling WaitLatch(). Make sure the WL_POSTMASTER_DEATH flag is set when calling that function, and verify the return code for a prompt exit in the emergency case that postgres itself has terminated.

When a background worker is registered using the RegisterDynamicBackgroundWorker function, it is possible for the backend performing the registration to obtain information regarding the status of the worker. Backends wishing to do this should

pass the address of a `BackgroundWorkerHandle *` as the second argument to `RegisterDynamicBackgroundWorker`. If the worker is successfully registered, this pointer will be initialized with an opaque handle that can subsequently be passed to `GetBackgroundWorkerPid(BackgroundWorkerHandle *, pid_t *)` or `TerminateBackgroundWorker(BackgroundWorkerHandle *)`. `GetBackgroundWorkerPid` can be used to poll the status of the worker: a return value of `BGWH_NOT_YET_STARTED` indicates that the worker has not yet been started by the postmaster; `BGWH_STOPPED` indicates that it has been started but is no longer running; and `BGWH_STARTED` indicates that it is currently running. In this last case, the PID will also be returned via the second argument. `TerminateBackgroundWorker` causes the postmaster to send `SIGTERM` to the worker if it is running, and to unregister it as soon as it is not.

In some cases, a process which registers a background worker may wish to wait for the worker to start up. This can be accomplished by initializing `bgw_notify_pid` to `MyProcPid` and then passing the `BackgroundWorkerHandle *` obtained at registration time to `WaitForBackgroundWorkerStartup(BackgroundWorkerHandle *handle, pid_t *)` function. This function will block until the postmaster has attempted to start the background worker, or until the postmaster dies. If the background runner is running, the return value will `BGWH_STARTED`, and the PID will be written to the provided address. Otherwise, the return value will be `BGWH_STOPPED` or `BGWH_POSTMASTER_DIED`.

The `worker_spi` contrib module contains a working example, which demonstrates some useful techniques.

The maximum number of registered background workers is limited by max_worker_processes.

Chapter 46. Logical Decoding

PostgreSQL provides infrastructure to stream the modifications performed via SQL to external consumers. This functionality can be used to for a variety of purposes, including replication solutions and auditing.

Changes are sent out in streams identified by logical replication slots. Each stream outputs each change exactly once.

The format in which those changes are streamed is determined by the output plugin used. An example plugin is provided in the PostgreSQL distribution. Additional plugins can be written to extend the choice of available formats without modifying any core code. Every output plugin has access to each individual new row produced by `INSERT` and the new row version created by `UPDATE`. Availability of old row versions for `UPDATE` and `DELETE` depends on the configured replica identity (see *`REPLICA IDENTITY`*).

Changes can be consumed either using the streaming replication protocol (see Section 49.3 and Section 46.3), or by calling functions via SQL (see Section 46.4). It is also possible to write additional methods of consuming the output of a replication slot without modifying core code (see Section 46.7).

46.1. Logical Decoding Examples

The following example demonstrates controlling logical decoding using the SQL interface.

Before you can use logical decoding, you must set wal_level to `logical` and max_replication_slots to at least 1. Then, you should connect to the target database (in the example below, `postgres`) as a superuser.

```
postgres=# -- Create a slot named 'regression_slot' using the output plugin 'test_decodi
postgres=# SELECT * FROM pg_create_logical_replication_slot('regression_slot', 'test_dec
    slot_name    | xlog_position
-----------------+---------------
 regression_slot | 0/16B1970
(1 row)

postgres=# SELECT * FROM pg_replication_slots;
    slot_name    |    plugin     | slot_type | datoid | database | active |  xmin  | cat
-----------------+---------------+-----------+--------+----------+--------+--------+----
 regression_slot | test_decoding | logical   |  12052 | postgres | f      |        |
(1 row)

postgres=# -- There are no changes to see yet
postgres=# SELECT * FROM pg_logical_slot_get_changes('regression_slot', NULL, NULL);
 location | xid | data
----------+-----+------
(0 rows)

postgres=# CREATE TABLE data(id serial primary key, data text);
CREATE TABLE

postgres=# -- DDL isn't replicated, so all you'll see is the transaction
postgres=# SELECT * FROM pg_logical_slot_get_changes('regression_slot', NULL, NULL);
 location  | xid |    data
-----------+-----+------------
 0/16D5D48 | 688 | BEGIN 688
```

```
 0/16E0380 | 688 | COMMIT 688
(2 rows)

postgres=# -- Once changes are read, they're consumed and not emitted
postgres=# -- in a subsequent call:
postgres=# SELECT * FROM pg_logical_slot_get_changes('regression_slot', NULL, NULL);
 location | xid | data
----------+-----+------
(0 rows)

postgres=# BEGIN;
postgres=# INSERT INTO data(data) VALUES('1');
postgres=# INSERT INTO data(data) VALUES('2');
postgres=# COMMIT;

postgres=# SELECT * FROM pg_logical_slot_get_changes('regression_slot', NULL, NULL);
 location  | xid |                      data
-----------+-----+-------------------------------------------------
 0/16E0478 | 689 | BEGIN 689
 0/16E0478 | 689 | table public.data: INSERT: id[integer]:1 data[text]:'1'
 0/16E0580 | 689 | table public.data: INSERT: id[integer]:2 data[text]:'2'
 0/16E0650 | 689 | COMMIT 689
(4 rows)

postgres=# INSERT INTO data(data) VALUES('3');

postgres=# -- You can also peek ahead in the change stream without consuming changes
postgres=# SELECT * FROM pg_logical_slot_peek_changes('regression_slot', NULL, NULL);
 location  | xid |                      data
-----------+-----+-------------------------------------------------
 0/16E09C0 | 690 | BEGIN 690
 0/16E09C0 | 690 | table public.data: INSERT: id[integer]:3 data[text]:'3'
 0/16E0B90 | 690 | COMMIT 690
(3 rows)

postgres=# -- The next call to pg_logical_slot_peek_changes() returns the same changes a
postgres=# SELECT * FROM pg_logical_slot_peek_changes('regression_slot', NULL, NULL);
 location  | xid |                      data
-----------+-----+-------------------------------------------------
 0/16E09C0 | 690 | BEGIN 690
 0/16E09C0 | 690 | table public.data: INSERT: id[integer]:3 data[text]:'3'
 0/16E0B90 | 690 | COMMIT 690
(3 rows)

postgres=# -- options can be passed to output plugin, to influence the formatting
postgres=# SELECT * FROM pg_logical_slot_peek_changes('regression_slot', NULL, NULL, 'in
 location  | xid |                      data
-----------+-----+-------------------------------------------------
 0/16E09C0 | 690 | BEGIN 690
 0/16E09C0 | 690 | table public.data: INSERT: id[integer]:3 data[text]:'3'
 0/16E0B90 | 690 | COMMIT 690 (at 2014-02-27 16:41:51.863092+01)
(3 rows)

postgres=# -- Remember to destroy a slot you no longer need to stop it consuming
postgres=# -- server resources:
postgres=# SELECT pg_drop_replication_slot('regression_slot');
 pg_drop_replication_slot
```

```
----------------------

(1 row)
```

The following example shows how logical decoding is controlled over the streaming replication protocol, using the program pg_recvlogical included in the PostgreSQL distribution. This requires that client authentication is set up to allow replication connections (see Section 25.2.5.1) and that `max_wal_senders` is set sufficiently high to an additional connection.

```
$ pg_recvlogical -d postgres --slot test --create-slot
$ pg_recvlogical -d postgres --slot test --start -f -
Control+Z
$ psql -d postgres -c "INSERT INTO data(data) VALUES('4');"
$ fg
BEGIN 693
table public.data: INSERT: id[integer]:4 data[text]:'4'
COMMIT 693
Control+C
$ pg_recvlogical -d postgres --slot test --drop-slot
```

46.2. Logical Decoding Concepts

46.2.1. Logical Decoding

Logical decoding is the process of extracting all persistent changes to a database's tables into a coherent, easy to understand format which can be interpreted without detailed knowledge of the database's internal state.

In PostgreSQL, logical decoding is implemented by decoding the contents of the write-ahead log, which describe changes on a storage level, into an application-specific form such as a stream of tuples or SQL statements.

46.2.2. Replication Slots

In the context of logical replication, a slot represents a stream of changes that can be replayed to a client in the order they were made on the origin server. Each slot streams a sequence of changes from a single database, sending each change exactly once (except when peeking forward in the stream).

> **Note:** PostgreSQL also has streaming replication slots (see Section 25.2.5), but they are used somewhat differently there.

A replication slot has an identifier that is unique across all databases in a PostgreSQL cluster. Slots persist independently of the connection using them and are crash-safe.

Multiple independent slots may exist for a single database. Each slot has its own state, allowing different consumers to receive changes from different points in the database change stream. For most applications, a separate slot will be required for each consumer.

A logical replication slot knows nothing about the state of the receiver(s). It's even possible to have multiple different receivers using the same slot at different times; they'll just get the changes following

on from when the last receiver stopped consuming them. Only one receiver may consume changes from a slot at any given time.

> **Note:** Replication slots persist across crashes and know nothing about the state of their consumer(s). They will prevent removal of required resources even when there is no connection using them. This consumes storage because neither required WAL nor required rows from the system catalogs can be removed by `VACUUM` as long as they are required by a replication slot. So if a slot is no longer required it should be dropped.

46.2.3. Output Plugins

Output plugins transform the data from the write-ahead log's internal representation into the format the consumer of a replication slot desires.

46.2.4. Exported Snapshots

When a new replication slot is created using the streaming replication interface, a snapshot is exported (see Section 9.26.5), which will show exactly the state of the database after which all changes will be included in the change stream. This can be used to create a new replica by using `SET TRANSACTION SNAPSHOT` to read the state of the database at the moment the slot was created. This transaction can then be used to dump the database's state at that point in time, which afterwards can be updated using the slot's contents without losing any changes.

46.3. Streaming Replication Protocol Interface

The commands

- `CREATE_REPLICATION_SLOT` *`slot_name`* `LOGICAL` *`options`*
- `DROP_REPLICATION_SLOT` *`slot_name`*
- `START_REPLICATION SLOT` *`slot_name`* `LOGICAL` *`options`*

are used to create, drop, and stream changes from a replication slot, respectively. These commands are only available over a replication connection; they cannot be used via SQL. See Section 49.3 for details on these commands.

The command pg_recvlogical can be used to control logical decoding over a streaming replication connection. (It is uses these commands internally.)

46.4. Logical Decoding SQL Interface

See Section 9.26.6 for detailed documentation on the SQL-level API for interacting with logical decoding.

Synchronous replication (see Section 25.2.8) is only supported on replication slots used over the streaming replication interface. The function interface and additional, non-core interfaces do not support synchronous replication.

46.5. System Catalogs Related to Logical Decoding

The `pg_replication_slots` view and the `pg_stat_replication` view provide information about the current state of replication slots and streaming replication connections respectively. These views apply to both physical and logical replication.

46.6. Logical Decoding Output Plugins

An example output plugin can be found in the `contrib/test_decoding` subdirectory of the PostgreSQL source tree.

46.6.1. Initialization Function

An output plugin is loaded by dynamically loading a shared library with the output plugin's name as the library base name. The normal library search path is used to locate the library. To provide the required output plugin callbacks and to indicate that the library is actually an output plugin it needs to provide a function named `_PG_output_plugin_init`. This function is passed a struct that needs to be filled with the callback function pointers for individual actions.

```
typedef struct OutputPluginCallbacks
{
    LogicalDecodeStartupCB startup_cb;
    LogicalDecodeBeginCB begin_cb;
    LogicalDecodeChangeCB change_cb;
    LogicalDecodeCommitCB commit_cb;
    LogicalDecodeShutdownCB shutdown_cb;
} OutputPluginCallbacks;

typedef void (*LogicalOutputPluginInit)(struct OutputPluginCallbacks *cb);
```

The `begin_cb`, `change_cb` and `commit_cb` callbacks are required, while `startup_cb` and `shutdown_cb` are optional.

46.6.2. Capabilities

To decode, format and output changes, output plugins can use most of the backend's normal infrastructure, including calling output functions. Read only access to relations is permitted as long as only relations are accessed that either have been created by `initdb` in the `pg_catalog` schema, or have been marked as user provided catalog tables using

```
ALTER TABLE user_catalog_table SET (user_catalog_table = true);
CREATE TABLE another_catalog_table(data text) WITH (user_catalog_table = true);
```

Any actions leading to transaction ID assignment are prohibited. That, among others, includes writing to tables, performing DDL changes, and calling `txid_current()`.

46.6.3. Output Modes

Output plugin callbacks can pass data to the consumer in nearly arbitrary formats. For some use cases, like viewing the changes via SQL, returning data in a data type that can contain arbitrary data (e.g., `bytea`) is cumbersome. If the output plugin only outputs textual data in the server's encoding, it can declare that by setting `OutputPluginOptions.output_mode` to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` instead of `OUTPUT_PLUGIN_BINARY_OUTPUT` in the startup callback. In that case, all the data has to be in the server's encoding so that a `text` datum can contain it. This is checked in assertion-enabled builds.

46.6.4. Output Plugin Callbacks

An output plugin gets notified about changes that are happening via various callbacks it needs to provide.

Concurrent transactions are decoded in commit order, and only changes belonging to a specific transaction are decoded between the `begin` and `commit` callbacks. Transactions that were rolled back explicitly or implicitly never get decoded. Successful savepoints are folded into the transaction containing them in the order they were executed within that transaction.

> **Note:** Only transactions that have already safely been flushed to disk will be decoded. That can lead to a `COMMIT` not immediately being decoded in a directly following `pg_logical_slot_get_changes()` when `synchronous_commit` is set to `off`.

46.6.4.1. Startup Callback

The optional `startup_cb` callback is called whenever a replication slot is created or asked to stream changes, independent of the number of changes that are ready to be put out.

```
typedef void (*LogicalDecodeStartupCB) (
    struct LogicalDecodingContext *ctx,
    OutputPluginOptions *options,
    bool is_init
);
```

The `is_init` parameter will be true when the replication slot is being created and false otherwise. `options` points to a struct of options that output plugins can set:

```
typedef struct OutputPluginOptions
{
    OutputPluginOutputType output_type;
} OutputPluginOptions;
```

`output_type` has to either be set to `OUTPUT_PLUGIN_TEXTUAL_OUTPUT` or `OUTPUT_PLUGIN_BINARY_OUTPUT`. See also Section 46.6.3>.

The startup callback should validate the options present in `ctx->output_plugin_options`. If the output plugin needs to have a state, it can use `ctx->output_plugin_private` to store it.

46.6.4.2. Shutdown Callback

The optional `shutdown_cb` callback is called whenever a formerly active replication slot is not used anymore and can be used to deallocate resources private to the output plugin. The slot isn't necessarily being dropped, streaming is just being stopped.

```
typedef void (*LogicalDecodeShutdownCB) (
    struct LogicalDecodingContext *ctx
);
```

46.6.4.3. Transaction Begin Callback

The required `begin_cb` callback is called whenever a start of a committed transaction has been decoded. Aborted transactions and their contents never get decoded.

```
typedef void (*LogicalDecodeBeginCB) (
    struct LogicalDecodingContext *,
    ReorderBufferTXN *txn
);
```

The `txn` parameter contains meta information about the transaction, like the time stamp at which it has been committed and its XID.

46.6.4.4. Transaction End Callback

The required `commit_cb` callback is called whenever a transaction commit has been decoded. The `change_cb` callbacks for all modified rows will have been called before this, if there have been any modified rows.

```
typedef void (*LogicalDecodeCommitCB) (
    struct LogicalDecodingContext *,
    ReorderBufferTXN *txn
);
```

46.6.4.5. Change Callback

The required `change_cb` callback is called for every individual row modification inside a transaction, may it be an `INSERT`, `UPDATE`, or `DELETE`. Even if the original command modified several rows at once the callback will be called individually for each row.

```
typedef void (*LogicalDecodeChangeCB) (
    struct LogicalDecodingContext *ctx,
    ReorderBufferTXN *txn,
    Relation relation,
    ReorderBufferChange *change
);
```

The `ctx` and `txn` parameters have the same contents as for the `begin_cb` and `commit_cb` callbacks, but additionally the relation descriptor `relation` points to the relation the row belongs to and a struct `change` describing the row modification are passed in.

Note: Only changes in user defined tables that are not unlogged (see *UNLOGGED*) and not temporary (see *TEMPORARY or TEMP*) can be extracted using logical decoding.

46.6.5. Functions for Producing Output

To actually produce output, output plugins can write data to the `StringInfo` output buffer in `ctx->out` when inside the `begin_cb`, `commit_cb`, or `change_cb` callbacks. Before writing to the output buffer, `OutputPluginPrepareWrite(ctx, last_write)` has to be called, and after finishing writing to the buffer, `OutputPluginWrite(ctx, last_write)` has to be called to perform the write. The `last_write` indicates whether a particular write was the callback's last write.

The following example shows how to output data to the consumer of an output plugin:

```
OutputPluginPrepareWrite(ctx, true);
appendStringInfo(ctx->out, "BEGIN %u", txn->xid);
OutputPluginWrite(ctx, true);
```

46.7. Logical Decoding Output Writers

It is possible to add more output methods for logical decoding. For details, see `src/backend/replication/logical/logicalfuncs.c`. Essentially, three functions need to be provided: one to read WAL, one to prepare writing output, and one to write the output (see Section 46.6.5).

46.8. Synchronous Replication Support for Logical Decoding

Logical decoding can be used to to build synchronous replication solutions with the same user interface as synchronous replication for streaming replication. To do this, the streaming replication interface (see Section 46.3) must be used to stream out data. Clients have to send `Standby status update (F)` (see Section 49.3) messages, just like streaming replication clients do.

Note: A synchronous replica receiving changes via logical decoding will work in the scope of a single database. Since, in contrast to that, `synchronous_standby_names` currently is server wide, this means this technique will not work properly if more than one database is actively used.

VI. Reference

The entries in this Reference are meant to provide in reasonable length an authoritative, complete, and formal summary about their respective subjects. More information about the use of PostgreSQL, in narrative, tutorial, or example form, can be found in other parts of this book. See the cross-references listed on each reference page.

The reference entries are also available as traditional “man” pages.

I. SQL Commands

This part contains reference information for the SQL commands supported by PostgreSQL. By “SQL” the language in general is meant; information about the standards conformance and compatibility of each command can be found on the respective reference page.

ABORT

Name

ABORT — abort the current transaction

Synopsis

```
ABORT [ WORK | TRANSACTION ]
```

Description

ABORT rolls back the current transaction and causes all the updates made by the transaction to be discarded. This command is identical in behavior to the standard SQL command ROLLBACK, and is present only for historical reasons.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Notes

Use COMMIT to successfully terminate a transaction.

Issuing ABORT outside of a transaction block emits a warning and otherwise has no effect.

Examples

To abort all changes:

```
ABORT;
```

Compatibility

This command is a PostgreSQL extension present for historical reasons. ROLLBACK is the equivalent standard SQL command.

See Also

BEGIN, COMMIT, ROLLBACK

ALTER AGGREGATE

Name

ALTER AGGREGATE — change the definition of an aggregate function

Synopsis

```
ALTER AGGREGATE name ( aggregate_signature ) RENAME TO new_name
ALTER AGGREGATE name ( aggregate_signature ) OWNER TO new_owner
ALTER AGGREGATE name ( aggregate_signature ) SET SCHEMA new_schema

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ] [ argname ] argtype [ , .
```

Description

ALTER AGGREGATE changes the definition of an aggregate function.

You must own the aggregate function to use ALTER AGGREGATE. To change the schema of an aggregate function, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the aggregate function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the aggregate function. However, a superuser can alter ownership of any aggregate function anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing aggregate function.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that ALTER AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write * in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

new_name

The new name of the aggregate function.

new_owner

The new owner of the aggregate function.

new_schema

The new schema for the aggregate function.

Notes

The recommended syntax for referencing an ordered-set aggregate is to write `ORDER BY` between the direct and aggregated argument specifications, in the same style as in CREATE AGGREGATE. However, it will also work to omit `ORDER BY` and just run the direct and aggregated argument specifications into a single list. In this abbreviated form, if `VARIADIC "any"` was used in both the direct and aggregated argument lists, write `VARIADIC "any"` only once.

Examples

To rename the aggregate function `myavg` for type `integer` to `my_average`:

```
ALTER AGGREGATE myavg(integer) RENAME TO my_average;
```

To change the owner of the aggregate function `myavg` for type `integer` to `joe`:

```
ALTER AGGREGATE myavg(integer) OWNER TO joe;
```

To move the ordered-set aggregate `mypercentile` with direct argument of type `float8` and aggregated argument of type `integer` into schema `myschema`:

```
ALTER AGGREGATE mypercentile(float8 ORDER BY integer) SET SCHEMA myschema;
```

This will work too:

```
ALTER AGGREGATE mypercentile(float8, integer) SET SCHEMA myschema;
```

Compatibility

There is no `ALTER AGGREGATE` statement in the SQL standard.

See Also

CREATE AGGREGATE, DROP AGGREGATE

ALTER COLLATION

Name

ALTER COLLATION — change the definition of a collation

Synopsis

```
ALTER COLLATION name RENAME TO new_name
ALTER COLLATION name OWNER TO new_owner
ALTER COLLATION name SET SCHEMA new_schema
```

Description

ALTER COLLATION changes the definition of a collation.

You must own the collation to use ALTER COLLATION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the collation's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the collation. However, a superuser can alter ownership of any collation anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing collation.

new_name

The new name of the collation.

new_owner

The new owner of the collation.

new_schema

The new schema for the collation.

Examples

To rename the collation de_DE to german:

```
ALTER COLLATION "de_DE" RENAME TO german;
```

To change the owner of the collation en_US to joe:

```
ALTER COLLATION "en_US" OWNER TO joe;
```

Compatibility

There is no `ALTER COLLATION` statement in the SQL standard.

See Also

CREATE COLLATION, DROP COLLATION

ALTER CONVERSION

Name

ALTER CONVERSION — change the definition of a conversion

Synopsis

```
ALTER CONVERSION name RENAME TO new_name
ALTER CONVERSION name OWNER TO new_owner
ALTER CONVERSION name SET SCHEMA new_schema
```

Description

ALTER CONVERSION changes the definition of a conversion.

You must own the conversion to use ALTER CONVERSION. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the conversion's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the conversion. However, a superuser can alter ownership of any conversion anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing conversion.

new_name

The new name of the conversion.

new_owner

The new owner of the conversion.

new_schema

The new schema for the conversion.

Examples

To rename the conversion iso_8859_1_to_utf8 to latin1_to_unicode:

```
ALTER CONVERSION iso_8859_1_to_utf8 RENAME TO latin1_to_unicode;
```

To change the owner of the conversion iso_8859_1_to_utf8 to joe:

```
ALTER CONVERSION iso_8859_1_to_utf8 OWNER TO joe;
```

Compatibility

There is no `ALTER CONVERSION` statement in the SQL standard.

See Also

CREATE CONVERSION, DROP CONVERSION

ALTER DATABASE

Name

ALTER DATABASE — change a database

Synopsis

```
ALTER DATABASE name [ [ WITH ] option [ ... ] ]

where option can be:

    CONNECTION LIMIT connlimit

ALTER DATABASE name RENAME TO new_name

ALTER DATABASE name OWNER TO new_owner

ALTER DATABASE name SET TABLESPACE new_tablespace

ALTER DATABASE name SET configuration_parameter { TO | = } { value | DEFAULT }
ALTER DATABASE name SET configuration_parameter FROM CURRENT
ALTER DATABASE name RESET configuration_parameter
ALTER DATABASE name RESET ALL
```

Description

ALTER DATABASE changes the attributes of a database.

The first form changes certain per-database settings. (See below for details.) Only the database owner or a superuser can change these settings.

The second form changes the name of the database. Only the database owner or a superuser can rename a database; non-superuser owners must also have the CREATEDB privilege. The current database cannot be renamed. (Connect to a different database if you need to do that.)

The third form changes the owner of the database. To alter the owner, you must own the database and also be a direct or indirect member of the new owning role, and you must have the CREATEDB privilege. (Note that superusers have all these privileges automatically.)

The fourth form changes the default tablespace of the database. Only the database owner or a superuser can do this; you must also have create privilege for the new tablespace. This command physically moves any tables or indexes in the database's old default tablespace to the new tablespace. Note that tables and indexes in non-default tablespaces are not affected.

The remaining forms change the session default for a run-time configuration variable for a PostgreSQL database. Whenever a new session is subsequently started in that database, the specified value becomes the session default value. The database-specific default overrides whatever setting is present in postgresql.conf or has been received from the postgres command line. Only the database owner or a superuser can change the session defaults for a database. Certain variables cannot be set this way, or can only be set by a superuser.

Parameters

name

The name of the database whose attributes are to be altered.

connlimit

How many concurrent connections can be made to this database. -1 means no limit.

new_name

The new name of the database.

new_owner

The new owner of the database.

new_tablespace

The new default tablespace of the database.

configuration_parameter
value

Set this database's session default for the specified configuration parameter to the given value. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the database-specific setting is removed, so the system-wide default setting will be inherited in new sessions. Use `RESET ALL` to clear all database-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter as the database-specific value.

See SET and Chapter 18 for more information about allowed parameter names and values.

Notes

It is also possible to tie a session default to a specific role rather than to a database; see ALTER ROLE. Role-specific settings override database-specific ones if there is a conflict.

Examples

To disable index scans by default in the database `test`:

```
ALTER DATABASE test SET enable_indexscan TO off;
```

Compatibility

The `ALTER DATABASE` statement is a PostgreSQL extension.

See Also

CREATE DATABASE, DROP DATABASE, SET, CREATE TABLESPACE

ALTER DEFAULT PRIVILEGES

Name

ALTER DEFAULT PRIVILEGES — define default access privileges

Synopsis

```
ALTER DEFAULT PRIVILEGES
    [ FOR { ROLE | USER } target_role [, ...] ]
    [ IN SCHEMA schema_name [, ...] ]
    abbreviated_grant_or_revoke

where abbreviated_grant_or_revoke is one of:

GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON TABLES
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON SEQUENCES
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [ PRIVILEGES ] }
    ON FUNCTIONS
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON TYPES
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON TABLES
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON SEQUENCES
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { EXECUTE | ALL [ PRIVILEGES ] }
    ON FUNCTIONS
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
```

```
ON TYPES
FROM { [ GROUP ] role_name | PUBLIC } [, ...]
[ CASCADE | RESTRICT ]
```

Description

ALTER DEFAULT PRIVILEGES allows you to set the privileges that will be applied to objects created in the future. (It does not affect privileges assigned to already-existing objects.) Currently, only the privileges for tables (including views and foreign tables), sequences, functions, and types (including domains) can be altered.

You can change default privileges only for objects that will be created by yourself or by roles that you are a member of. The privileges can be set globally (i.e., for all objects created in the current database), or just for objects created in specified schemas. Default privileges that are specified per-schema are added to whatever the global default privileges are for the particular object type.

As explained under GRANT, the default privileges for any object type normally grant all grantable permissions to the object owner, and may grant some privileges to PUBLIC as well. However, this behavior can be changed by altering the global default privileges with ALTER DEFAULT PRIVILEGES.

Parameters

target_role

The name of an existing role of which the current role is a member. If FOR ROLE is omitted, the current role is assumed.

schema_name

The name of an existing schema. If specified, the default privileges are altered for objects later created in that schema. If IN SCHEMA is omitted, the global default privileges are altered.

role_name

The name of an existing role to grant or revoke privileges for. This parameter, and all the other parameters in *abbreviated_grant_or_revoke*, act as described under GRANT or REVOKE, except that one is setting permissions for a whole class of objects rather than specific named objects.

Notes

Use psql's \ddp command to obtain information about existing assignments of default privileges. The meaning of the privilege values is the same as explained for \dp under GRANT.

If you wish to drop a role for which the default privileges have been altered, it is necessary to reverse the changes in its default privileges or use DROP OWNED BY to get rid of the default privileges entry for the role.

Examples

Grant SELECT privilege to everyone for all tables (and views) you subsequently create in schema `myschema`, and allow role `webuser` to INSERT into them too:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT SELECT ON TABLES TO PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema GRANT INSERT ON TABLES TO webuser;
```

Undo the above, so that subsequently-created tables won't have any more permissions than normal:

```
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE SELECT ON TABLES FROM PUBLIC;
ALTER DEFAULT PRIVILEGES IN SCHEMA myschema REVOKE INSERT ON TABLES FROM webuser;
```

Remove the public EXECUTE permission that is normally granted on functions, for all functions subsequently created by role `admin`:

```
ALTER DEFAULT PRIVILEGES FOR ROLE admin REVOKE EXECUTE ON FUNCTIONS FROM PUBLIC;
```

Compatibility

There is no `ALTER DEFAULT PRIVILEGES` statement in the SQL standard.

See Also

GRANT, REVOKE

ALTER DOMAIN

Name

ALTER DOMAIN — change the definition of a domain

Synopsis

```
ALTER DOMAIN name
    { SET DEFAULT expression | DROP DEFAULT }
ALTER DOMAIN name
    { SET | DROP } NOT NULL
ALTER DOMAIN name
    ADD domain_constraint [ NOT VALID ]
ALTER DOMAIN name
    DROP CONSTRAINT [ IF EXISTS ] constraint_name [ RESTRICT | CASCADE ]
ALTER DOMAIN name
     RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER DOMAIN name
    VALIDATE CONSTRAINT constraint_name
ALTER DOMAIN name
    OWNER TO new_owner
ALTER DOMAIN name
    RENAME TO new_name
ALTER DOMAIN name
    SET SCHEMA new_schema
```

Description

ALTER DOMAIN changes the definition of an existing domain. There are several sub-forms:

SET/DROP DEFAULT

These forms set or remove the default value for a domain. Note that defaults only apply to subsequent INSERT commands; they do not affect rows already in a table using the domain.

SET/DROP NOT NULL

These forms change whether a domain is marked to allow NULL values or to reject NULL values. You can only SET NOT NULL when the columns using the domain contain no null values.

ADD *domain_constraint* [NOT VALID]

This form adds a new constraint to a domain using the same syntax as CREATE DOMAIN. When a new constraint is added to a domain, all columns using that domain will be checked against the newly added constraint. These checks can be suppressed by adding the new constraint using the NOT VALID option; the constraint can later be made valid using ALTER DOMAIN ... VALIDATE CONSTRAINT. Newly inserted or updated rows are always checked against all constraints, even those marked NOT VALID. NOT VALID is only accepted for CHECK constraints.

DROP CONSTRAINT [IF EXISTS]

This form drops constraints on a domain. If IF EXISTS is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

RENAME CONSTRAINT

This form changes the name of a constraint on a domain.

VALIDATE CONSTRAINT

This form validates a constraint previously added as `NOT VALID`, that is, verify that all data in columns using the domain satisfy the specified constraint.

OWNER

This form changes the owner of the domain to the specified user.

`RENAME`

This form changes the name of the domain.

SET SCHEMA

This form changes the schema of the domain. Any constraints associated with the domain are moved into the new schema as well.

You must own the domain to use `ALTER DOMAIN`. To change the schema of a domain, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the domain's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the domain. However, a superuser can alter ownership of any domain anyway.)

Parameters

`name`

The name (possibly schema-qualified) of an existing domain to alter.

`domain_constraint`

New domain constraint for the domain.

`constraint_name`

Name of an existing constraint to drop or rename.

`NOT VALID`

Do not verify existing column data for constraint validity.

`CASCADE`

Automatically drop objects that depend on the constraint.

`RESTRICT`

Refuse to drop the constraint if there are any dependent objects. This is the default behavior.

`new_name`

The new name for the domain.

`new_constraint_name`

The new name for the constraint.

`new_owner`

The user name of the new owner of the domain.

new_schema

The new schema for the domain.

Notes

Currently, `ALTER DOMAIN ADD CONSTRAINT` and `ALTER DOMAIN SET NOT NULL` will fail if the named domain or any derived domain is used within a composite-type column of any table in the database. They should eventually be improved to be able to verify the new constraint for such nested columns.

Examples

To add a `NOT NULL` constraint to a domain:

```
ALTER DOMAIN zipcode SET NOT NULL;
```

To remove a `NOT NULL` constraint from a domain:

```
ALTER DOMAIN zipcode DROP NOT NULL;
```

To add a check constraint to a domain:

```
ALTER DOMAIN zipcode ADD CONSTRAINT zipchk CHECK (char_length(VALUE) = 5);
```

To remove a check constraint from a domain:

```
ALTER DOMAIN zipcode DROP CONSTRAINT zipchk;
```

To rename a check constraint on a domain:

```
ALTER DOMAIN zipcode RENAME CONSTRAINT zipchk TO zip_check;
```

To move the domain into a different schema:

```
ALTER DOMAIN zipcode SET SCHEMA customers;
```

Compatibility

`ALTER DOMAIN` conforms to the SQL standard, except for the `OWNER`, `RENAME`, `SET SCHEMA`, and `VALIDATE CONSTRAINT` variants, which are PostgreSQL extensions. The `NOT VALID` clause of the `ADD CONSTRAINT` variant is also a PostgreSQL extension.

See Also

CREATE DOMAIN, DROP DOMAIN

ALTER EVENT TRIGGER

Name

ALTER EVENT TRIGGER — change the definition of an event trigger

Synopsis

```
ALTER EVENT TRIGGER name DISABLE
ALTER EVENT TRIGGER name ENABLE [ REPLICA | ALWAYS ]
ALTER EVENT TRIGGER name OWNER TO new_owner
ALTER EVENT TRIGGER name RENAME TO new_name
```

Description

ALTER EVENT TRIGGER changes properties of an existing event trigger.

You must be superuser to alter an event trigger.

Parameters

name

The name of an existing trigger to alter.

new_owner

The user name of the new owner of the event trigger.

new_name

The new name of the event trigger.

DISABLE/ENABLE [REPLICA | ALWAYS] TRIGGER

These forms configure the firing of event triggers. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. See also session_replication_role.

Compatibility

There is no ALTER EVENT TRIGGER statement in the SQL standard.

See Also

CREATE EVENT TRIGGER, DROP EVENT TRIGGER

ALTER EXTENSION

Name

ALTER EXTENSION — change the definition of an extension

Synopsis

```
ALTER EXTENSION name UPDATE [ TO new_version ]
ALTER EXTENSION name SET SCHEMA new_schema
ALTER EXTENSION name ADD member_object
ALTER EXTENSION name DROP member_object

where member_object is:

  AGGREGATE aggregate_name ( aggregate_signature ) |
  CAST (source_type AS target_type) |
  COLLATION object_name |
  CONVERSION object_name |
  DOMAIN object_name |
  EVENT TRIGGER object_name |
  FOREIGN DATA WRAPPER object_name |
  FOREIGN TABLE object_name |
  FUNCTION function_name ( [ [ argmode ] [ argname ] argtype [, ...] ] ) |
  MATERIALIZED VIEW object_name |
  OPERATOR operator_name (left_type, right_type) |
  OPERATOR CLASS object_name USING index_method |
  OPERATOR FAMILY object_name USING index_method |
  [ PROCEDURAL ] LANGUAGE object_name |
  SCHEMA object_name |
  SEQUENCE object_name |
  SERVER object_name |
  TABLE object_name |
  TEXT SEARCH CONFIGURATION object_name |
  TEXT SEARCH DICTIONARY object_name |
  TEXT SEARCH PARSER object_name |
  TEXT SEARCH TEMPLATE object_name |
  TYPE object_name |
  VIEW object_name

and aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ] [ argname ] argtype [ , .
```

Description

ALTER EXTENSION changes the definition of an installed extension. There are several subforms:

UPDATE

This form updates the extension to a newer version. The extension must supply a suitable update script (or series of scripts) that can modify the currently-installed version into the requested version.

SET SCHEMA

This form moves the extension's objects into another schema. The extension has to be *relocatable* for this command to succeed.

ADD *member_object*

This form adds an existing object to the extension. This is mainly useful in extension update scripts. The object will subsequently be treated as a member of the extension; notably, it can only be dropped by dropping the extension.

DROP *member_object*

This form removes a member object from the extension. This is mainly useful in extension update scripts. The object is not dropped, only disassociated from the extension.

See Section 35.15 for more information about these operations.

You must own the extension to use ALTER EXTENSION. The ADD/DROP forms require ownership of the added/dropped object as well.

Parameters

name

The name of an installed extension.

new_version

The desired new version of the extension. This can be written as either an identifier or a string literal. If not specified, ALTER EXTENSION UPDATE attempts to update to whatever is shown as the default version in the extension's control file.

new_schema

The new schema for the extension.

object_name
aggregate_name
function_name
operator_name

The name of an object to be added to or removed from the extension. Names of tables, aggregates, domains, foreign tables, functions, operators, operator classes, operator families, sequences, text search objects, types, and views can be schema-qualified.

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

argmode

The mode of a function or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER EXTENSION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of a function or aggregate argument. Note that ALTER EXTENSION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function or aggregate argument.

left_type
right_type

The data type(s) of the operator's arguments (optionally schema-qualified). Write NONE for the missing argument of a prefix or postfix operator.

PROCEDURAL

This is a noise word.

Examples

To update the hstore extension to version 2.0:

```
ALTER EXTENSION hstore UPDATE TO '2.0';
```

To change the schema of the hstore extension to utils:

```
ALTER EXTENSION hstore SET SCHEMA utils;
```

To add an existing function to the hstore extension:

```
ALTER EXTENSION hstore ADD FUNCTION populate_record(anyelement, hstore);
```

Compatibility

ALTER EXTENSION is a PostgreSQL extension.

See Also

CREATE EXTENSION, DROP EXTENSION

ALTER FOREIGN DATA WRAPPER

Name

ALTER FOREIGN DATA WRAPPER — change the definition of a foreign-data wrapper

Synopsis

```
ALTER FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ]) ]
ALTER FOREIGN DATA WRAPPER name OWNER TO new_owner
ALTER FOREIGN DATA WRAPPER name RENAME TO new_name
```

Description

ALTER FOREIGN DATA WRAPPER changes the definition of a foreign-data wrapper. The first form of the command changes the support functions or the generic options of the foreign-data wrapper (at least one clause is required). The second form changes the owner of the foreign-data wrapper.

Only superusers can alter foreign-data wrappers. Additionally, only superusers can own foreign-data wrappers.

Parameters

name

The name of an existing foreign-data wrapper.

HANDLER *handler_function*

Specifies a new handler function for the foreign-data wrapper.

NO HANDLER

This is used to specify that the foreign-data wrapper should no longer have a handler function.

Note that foreign tables that use a foreign-data wrapper with no handler cannot be accessed.

VALIDATOR *validator_function*

Specifies a new validator function for the foreign-data wrapper.

Note that it is possible that pre-existing options of the foreign-data wrapper, or of dependent servers, user mappings, or foreign tables, are invalid according to the new validator. PostgreSQL does not check for this. It is up to the user to make sure that these options are correct before using the modified foreign-data wrapper. However, any options specified in this ALTER FOREIGN DATA WRAPPER command will be checked using the new validator.

NO VALIDATOR

This is used to specify that the foreign-data wrapper should no longer have a validator function.

`OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )`

Change options for the foreign-data wrapper. `ADD`, `SET`, and `DROP` specify the action to be performed. `ADD` is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the foreign data wrapper's validator function, if any.

new_owner

The user name of the new owner of the foreign-data wrapper.

new_name

The new name for the foreign-data wrapper.

Examples

Change a foreign-data wrapper `dbi`, add option `foo`, drop `bar`:

```
ALTER FOREIGN DATA WRAPPER dbi OPTIONS (ADD foo '1', DROP 'bar');
```

Change the foreign-data wrapper `dbi` validator to `bob.myvalidator`:

```
ALTER FOREIGN DATA WRAPPER dbi VALIDATOR bob.myvalidator;
```

Compatibility

`ALTER FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), except that the `HANDLER`, `VALIDATOR`, `OWNER TO`, and `RENAME` clauses are extensions.

See Also

CREATE FOREIGN DATA WRAPPER, DROP FOREIGN DATA WRAPPER

ALTER FOREIGN TABLE

Name

ALTER FOREIGN TABLE — change the definition of a foreign table

Synopsis

```
ALTER FOREIGN TABLE [ IF EXISTS ] name
    action [, ... ]
ALTER FOREIGN TABLE [ IF EXISTS ] name
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER FOREIGN TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
```

where *action* is one of:

```
    ADD [ COLUMN ] column_name data_type [ COLLATE collation ] [ column_constraint [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT | CASCADE ]
    ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type
    ALTER [ COLUMN ] column_name SET DEFAULT expression
    ALTER [ COLUMN ] column_name DROP DEFAULT
    ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value [, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option [, ... ] )
    ALTER [ COLUMN ] column_name OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ])
    DISABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE REPLICA TRIGGER trigger_name
    ENABLE ALWAYS TRIGGER trigger_name
    OWNER TO new_owner
    OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ])
```

Description

ALTER FOREIGN TABLE changes the definition of an existing foreign table. There are several subforms:

ADD COLUMN

This form adds a new column to the foreign table, using the same syntax as CREATE FOREIGN TABLE. Unlike the case when adding a column to a regular table, nothing happens to the underlying storage: this action simply declares that some new column is now accessible through the foreign table.

DROP COLUMN [IF EXISTS]

This form drops a column from a foreign table. You will need to say CASCADE if anything outside the table depends on the column; for example, views. If IF EXISTS is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

`IF EXISTS`

Do not throw an error if the foreign table does not exist. A notice is issued in this case.

`SET DATA TYPE`

This form changes the type of a column of a foreign table.

`SET/DROP DEFAULT`

These forms set or remove the default value for a column. Default values only apply in subsequent `INSERT` or `UPDATE` commands; they do not cause rows already in the table to change.

`SET/DROP NOT NULL`

Mark a column as allowing, or not allowing, null values.

`SET STATISTICS`

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations. See the similar form of ALTER TABLE for more details.

`SET ( attribute_option = value [, ... ] )`
`RESET ( attribute_option [, ... ] )`

This form sets or resets per-attribute options. See the similar form of ALTER TABLE for more details.

`DISABLE/ENABLE [ REPLICA | ALWAYS ] TRIGGER`

These forms configure the firing of trigger(s) belonging to the foreign table. See the similar form of ALTER TABLE for more details.

`OWNER`

This form changes the owner of the foreign table to the specified user.

`RENAME`

The `RENAME` forms change the name of a foreign table or the name of an individual column in a foreign table.

`SET SCHEMA`

This form moves the foreign table into another schema.

`OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )`

Change options for the foreign table or one of its columns. `ADD`, `SET`, and `DROP` specify the action to be performed. `ADD` is assumed if no operation is explicitly specified. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name). Option names and values are also validated using the foreign data wrapper library.

All the actions except `RENAME` and `SET SCHEMA` can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several columns and/or alter the type of several columns in a single command.

You must own the table to use `ALTER FOREIGN TABLE`. To change the schema of a foreign table, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type, you must also have `USAGE` privilege on the data type.

Parameters

name

The name (possibly schema-qualified) of an existing foreign table to alter.

column_name

Name of a new or existing column.

new_column_name

New name for an existing column.

new_name

New name for the table.

data_type

Data type of the new column, or new data type for an existing column.

CASCADE

Automatically drop objects that depend on the dropped column (for example, views referencing the column).

RESTRICT

Refuse to drop the column if there are any dependent objects. This is the default behavior.

trigger_name

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the foreign table. (This requires superuser privilege if any of the triggers are internally generated triggers. The core system does not add such triggers to foreign tables, but add-on code could do so.)

USER

Disable or enable all triggers belonging to the foreign table except for internally generated triggers.

new_owner

The user name of the new owner of the table.

new_schema

The name of the schema to which the table will be moved.

Notes

The key word COLUMN is noise and can be omitted.

Consistency with the foreign server is not checked when a column is added or removed with ADD COLUMN or DROP COLUMN, a NOT NULL constraint is added, or a column type is changed with SET DATA TYPE. It is the user's responsibility to ensure that the table definition matches the remote side.

Refer to CREATE FOREIGN TABLE for a further description of valid parameters.

Examples

To mark a column as not-null:

```
ALTER FOREIGN TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To change options of a foreign table:

```
ALTER FOREIGN TABLE myschema.distributors OPTIONS (ADD opt1 'value', SET opt2, 'value2',
```

Compatibility

The forms `ADD`, `DROP`, and `SET DATA TYPE` conform with the SQL standard. The other forms are PostgreSQL extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER FOREIGN TABLE` command is an extension.

`ALTER FOREIGN TABLE DROP COLUMN` can be used to drop the only column of a foreign table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column foreign tables.

ALTER FUNCTION

Name

ALTER FUNCTION — change the definition of a function

Synopsis

```
ALTER FUNCTION name ( [ [ argmode ] [ argname ] argtype [, ...] ] )
    action [ ... ] [ RESTRICT ]
ALTER FUNCTION name ( [ [ argmode ] [ argname ] argtype [, ...] ] )
    RENAME TO new_name
ALTER FUNCTION name ( [ [ argmode ] [ argname ] argtype [, ...] ] )
    OWNER TO new_owner
ALTER FUNCTION name ( [ [ argmode ] [ argname ] argtype [, ...] ] )
    SET SCHEMA new_schema
```

where *action* is one of:

```
    CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
    IMMUTABLE | STABLE | VOLATILE | [ NOT ] LEAKPROOF
    [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
    COST execution_cost
    ROWS result_rows
    SET configuration_parameter { TO | = } { value | DEFAULT }
    SET configuration_parameter FROM CURRENT
    RESET configuration_parameter
    RESET ALL
```

Description

ALTER FUNCTION changes the definition of a function.

You must own the function to use ALTER FUNCTION. To change a function's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the function's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the function. However, a superuser can alter ownership of any function anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing function.

argmode

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of an argument. Note that ALTER FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any.

new_name

The new name of the function.

new_owner

The new owner of the function. Note that if the function is marked SECURITY DEFINER, it will subsequently execute as the new owner.

new_schema

The new schema for the function.

CALLED ON NULL INPUT
RETURNS NULL ON NULL INPUT
STRICT

CALLED ON NULL INPUT changes the function so that it will be invoked when some or all of its arguments are null. RETURNS NULL ON NULL INPUT or STRICT changes the function so that it is not invoked if any of its arguments are null; instead, a null result is assumed automatically. See CREATE FUNCTION for more information.

IMMUTABLE
STABLE
VOLATILE

Change the volatility of the function to the specified setting. See CREATE FUNCTION for details.

[EXTERNAL] SECURITY INVOKER
[EXTERNAL] SECURITY DEFINER

Change whether the function is a security definer or not. The key word EXTERNAL is ignored for SQL conformance. See CREATE FUNCTION for more information about this capability.

LEAKPROOF

Change whether the function is considered leakproof or not. See CREATE FUNCTION for more information about this capability.

COST *execution_cost*

Change the estimated execution cost of the function. See CREATE FUNCTION for more information.

ROWS *result_rows*

Change the estimated number of rows returned by a set-returning function. See CREATE FUNCTION for more information.

configuration_parameter
value

Add or change the assignment to be made to a configuration parameter when the function is called. If *value* is DEFAULT or, equivalently, RESET is used, the function-local setting is removed, so that the function executes with the value present in its environment. Use RESET ALL

to clear all function-local settings. SET FROM CURRENT saves the session's current value of the parameter as the value to be applied when the function is entered.

See SET and Chapter 18 for more information about allowed parameter names and values.

RESTRICT

Ignored for conformance with the SQL standard.

Examples

To rename the function sqrt for type integer to square_root:

```
ALTER FUNCTION sqrt(integer) RENAME TO square_root;
```

To change the owner of the function sqrt for type integer to joe:

```
ALTER FUNCTION sqrt(integer) OWNER TO joe;
```

To change the schema of the function sqrt for type integer to maths:

```
ALTER FUNCTION sqrt(integer) SET SCHEMA maths;
```

To adjust the search path that is automatically set for a function:

```
ALTER FUNCTION check_password(text) SET search_path = admin, pg_temp;
```

To disable automatic setting of search_path for a function:

```
ALTER FUNCTION check_password(text) RESET search_path;
```

The function will now execute with whatever search path is used by its caller.

Compatibility

This statement is partially compatible with the ALTER FUNCTION statement in the SQL standard. The standard allows more properties of a function to be modified, but does not provide the ability to rename a function, make a function a security definer, attach configuration parameter values to a function, or change the owner, schema, or volatility of a function. The standard also requires the RESTRICT key word, which is optional in PostgreSQL.

See Also

CREATE FUNCTION, DROP FUNCTION

ALTER GROUP

Name

ALTER GROUP — change role name or membership

Synopsis

```
ALTER GROUP group_name ADD USER user_name [, ... ]
ALTER GROUP group_name DROP USER user_name [, ... ]

ALTER GROUP group_name RENAME TO new_name
```

Description

ALTER GROUP changes the attributes of a user group. This is an obsolete command, though still accepted for backwards compatibility, because groups (and users too) have been superseded by the more general concept of roles.

The first two variants add users to a group or remove them from a group. (Any role can play the part of either a "user" or a "group" for this purpose.) These variants are effectively equivalent to granting or revoking membership in the role named as the "group"; so the preferred way to do this is to use GRANT or REVOKE.

The third variant changes the name of the group. This is exactly equivalent to renaming the role with ALTER ROLE.

Parameters

group_name

The name of the group (role) to modify.

user_name

Users (roles) that are to be added to or removed from the group. The users must already exist; ALTER GROUP does not create or drop users.

new_name

The new name of the group.

Examples

Add users to a group:

```
ALTER GROUP staff ADD USER karl, john;
```

Remove a user from a group:

```
ALTER GROUP workers DROP USER beth;
```

Compatibility

There is no `ALTER GROUP` statement in the SQL standard.

See Also

GRANT, REVOKE, ALTER ROLE

ALTER INDEX

Name

ALTER INDEX — change the definition of an index

Synopsis

```
ALTER INDEX [ IF EXISTS ] name RENAME TO new_name
ALTER INDEX [ IF EXISTS ] name SET TABLESPACE tablespace_name
ALTER INDEX [ IF EXISTS ] name SET ( storage_parameter = value [, ... ] )
ALTER INDEX [ IF EXISTS ] name RESET ( storage_parameter [, ... ] )
ALTER INDEX ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]
```

Description

ALTER INDEX changes the definition of an existing index. There are several subforms:

IF EXISTS

Do not throw an error if the index does not exist. A notice is issued in this case.

RENAME

The RENAME form changes the name of the index. There is no effect on the stored data.

SET TABLESPACE

This form changes the index's tablespace to the specified tablespace and moves the data file(s) associated with the index to the new tablespace. To change the tablespace of an index, you must own the index and have CREATE privilege on the new tablespace. All indexes in the current database in a tablespace can be moved by using the ALL IN TABLESPACE form, which will lock all indexes to be moved and then move each one. This form also supports OWNED BY, which will only move indexes owned by the roles specified. If the NOWAIT option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs will not be moved by this command, use ALTER DATABASE or explicit ALTER INDEX invocations instead if desired. See also CREATE TABLESPACE.

SET (*storage_parameter* = *value* [, ...])

This form changes one or more index-method-specific storage parameters for the index. See CREATE INDEX for details on the available parameters. Note that the index contents will not be modified immediately by this command; depending on the parameter you might need to rebuild the index with REINDEX to get the desired effects.

RESET (*storage_parameter* [, ...])

This form resets one or more index-method-specific storage parameters to their defaults. As with SET, a REINDEX might be needed to update the index entirely.

Parameters

name

The name (possibly schema-qualified) of an existing index to alter.

new_name

The new name for the index.

tablespace_name

The tablespace to which the index will be moved.

storage_parameter

The name of an index-method-specific storage parameter.

value

The new value for an index-method-specific storage parameter. This might be a number or a word depending on the parameter.

Notes

These operations are also possible using ALTER TABLE. `ALTER INDEX` is in fact just an alias for the forms of `ALTER TABLE` that apply to indexes.

There was formerly an `ALTER INDEX OWNER` variant, but this is now ignored (with a warning). An index cannot have an owner different from its table's owner. Changing the table's owner automatically changes the index as well.

Changing any part of a system catalog index is not permitted.

Examples

To rename an existing index:

```
ALTER INDEX distributors RENAME TO suppliers;
```

To move an index to a different tablespace:

```
ALTER INDEX distributors SET TABLESPACE fasttablespace;
```

To change an index's fill factor (assuming that the index method supports it):

```
ALTER INDEX distributors SET (fillfactor = 75);
REINDEX INDEX distributors;
```

Compatibility

`ALTER INDEX` is a PostgreSQL extension.

See Also

CREATE INDEX, REINDEX

ALTER LANGUAGE

Name

ALTER LANGUAGE — change the definition of a procedural language

Synopsis

```
ALTER [ PROCEDURAL ] LANGUAGE name RENAME TO new_name
ALTER [ PROCEDURAL ] LANGUAGE name OWNER TO new_owner
```

Description

ALTER LANGUAGE changes the definition of a procedural language. The only functionality is to rename the language or assign a new owner. You must be superuser or owner of the language to use ALTER LANGUAGE.

Parameters

name

Name of a language

new_name

The new name of the language

new_owner

The new owner of the language

Compatibility

There is no ALTER LANGUAGE statement in the SQL standard.

See Also

CREATE LANGUAGE, DROP LANGUAGE

ALTER LARGE OBJECT

Name

ALTER LARGE OBJECT — change the definition of a large object

Synopsis

```
ALTER LARGE OBJECT large_object_oid OWNER TO new_owner
```

Description

ALTER LARGE OBJECT changes the definition of a large object. The only functionality is to assign a new owner. You must be superuser or owner of the large object to use ALTER LARGE OBJECT.

Parameters

large_object_oid

OID of the large object to be altered

new_owner

The new owner of the large object

Compatibility

There is no ALTER LARGE OBJECT statement in the SQL standard.

See Also

Chapter 32

ALTER MATERIALIZED VIEW

Name

ALTER MATERIALIZED VIEW — change the definition of a materialized view

Synopsis

```
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    action [, ... ]
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    RENAME TO new_name
ALTER MATERIALIZED VIEW [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER MATERIALIZED VIEW ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]

where action is one of:

    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value [, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option [, ... ] )
    ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL | EXTENDED | MAIN }
    CLUSTER ON index_name
    SET WITHOUT CLUSTER
    SET ( storage_parameter = value [, ... ] )
    RESET ( storage_parameter [, ... ] )
    OWNER TO new_owner
    SET TABLESPACE new_tablespace
```

Description

ALTER MATERIALIZED VIEW changes various auxiliary properties of an existing materialized view.

You must own the materialized view to use ALTER MATERIALIZED VIEW. To change a materialized view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the materialized view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the materialized view. However, a superuser can alter ownership of any view anyway.)

The statement subforms and actions available for ALTER MATERIALIZED VIEW are a subset of those available for ALTER TABLE, and have the same meaning when used for materialized views. See the descriptions for ALTER TABLE for details.

Parameters

name

The name (optionally schema-qualified) of an existing materialized view.

column_name

Name of a new or existing column.

new_column_name

New name for an existing column.

new_owner

The user name of the new owner of the materialized view.

new_name

The new name for the materialized view.

new_schema

The new schema for the materialized view.

Examples

To rename the materialized view `foo` to `bar`:

```
ALTER MATERIALIZED VIEW foo RENAME TO bar;
```

Compatibility

`ALTER MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

CREATE MATERIALIZED VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

ALTER OPERATOR

Name

ALTER OPERATOR — change the definition of an operator

Synopsis

```
ALTER OPERATOR name ( { left_type | NONE } , { right_type | NONE } ) OWNER TO new_owner
ALTER OPERATOR name ( { left_type | NONE } , { right_type | NONE } ) SET SCHEMA new_schema
```

Description

ALTER OPERATOR changes the definition of an operator. The only currently available functionality is to change the owner of the operator.

You must own the operator to use ALTER OPERATOR. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator. However, a superuser can alter ownership of any operator anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing operator.

left_type

The data type of the operator's left operand; write NONE if the operator has no left operand.

right_type

The data type of the operator's right operand; write NONE if the operator has no right operand.

new_owner

The new owner of the operator.

new_schema

The new schema for the operator.

Examples

Change the owner of a custom operator a @@ b for type text:

```
ALTER OPERATOR @@ (text, text) OWNER TO joe;
```

Compatibility

There is no `ALTER OPERATOR` statement in the SQL standard.

See Also

CREATE OPERATOR, DROP OPERATOR

ALTER OPERATOR CLASS

Name

ALTER OPERATOR CLASS — change the definition of an operator class

Synopsis

```
ALTER OPERATOR CLASS name USING index_method RENAME TO new_name
ALTER OPERATOR CLASS name USING index_method OWNER TO new_owner
ALTER OPERATOR CLASS name USING index_method SET SCHEMA new_schema
```

Description

ALTER OPERATOR CLASS changes the definition of an operator class.

You must own the operator class to use ALTER OPERATOR CLASS. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the operator class's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the operator class. However, a superuser can alter ownership of any operator class anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing operator class.

index_method

The name of the index method this operator class is for.

new_name

The new name of the operator class.

new_owner

The new owner of the operator class.

new_schema

The new schema for the operator class.

Compatibility

There is no ALTER OPERATOR CLASS statement in the SQL standard.

See Also

CREATE OPERATOR CLASS, DROP OPERATOR CLASS, ALTER OPERATOR FAMILY

ALTER OPERATOR FAMILY

Name

ALTER OPERATOR FAMILY — change the definition of an operator family

Synopsis

```
ALTER OPERATOR FAMILY name USING index_method ADD
  {  OPERATOR strategy_number operator_name ( op_type, op_type ) [ FOR SEARCH | FOR ORDER BY
   | FUNCTION support_number [ ( op_type [ , op_type ] ) ] function_name ( argument_type [, .
  } [, ... ]
ALTER OPERATOR FAMILY name USING index_method DROP
  {  OPERATOR strategy_number ( op_type [ , op_type ] )
   | FUNCTION support_number ( op_type [ , op_type ] )
  } [, ... ]
ALTER OPERATOR FAMILY name USING index_method RENAME TO new_name
ALTER OPERATOR FAMILY name USING index_method OWNER TO new_owner
ALTER OPERATOR FAMILY name USING index_method SET SCHEMA new_schema
```

Description

ALTER OPERATOR FAMILY changes the definition of an operator family. You can add operators and support functions to the family, remove them from the family, or change the family's name or owner.

When operators and support functions are added to a family with ALTER OPERATOR FAMILY, they are not part of any specific operator class within the family, but are just "loose" within the family. This indicates that these operators and functions are compatible with the family's semantics, but are not required for correct functioning of any specific index. (Operators and functions that are so required should be declared as part of an operator class, instead; see CREATE OPERATOR CLASS.) PostgreSQL will allow loose members of a family to be dropped from the family at any time, but members of an operator class cannot be dropped without dropping the whole class and any indexes that depend on it. Typically, single-data-type operators and functions are part of operator classes because they are needed to support an index on that specific data type, while cross-data-type operators and functions are made loose members of the family.

You must be a superuser to use ALTER OPERATOR FAMILY. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

ALTER OPERATOR FAMILY does not presently check whether the operator family definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator family.

Refer to Section 35.14 for further information.

Parameters

name

The name (optionally schema-qualified) of an existing operator family.

index_method

The name of the index method this operator family is for.

strategy_number

The index method's strategy number for an operator associated with the operator family.

operator_name

The name (optionally schema-qualified) of an operator associated with the operator family.

op_type

In an OPERATOR clause, the operand data type(s) of the operator, or NONE to signify a left-unary or right-unary operator. Unlike the comparable syntax in CREATE OPERATOR CLASS, the operand data types must always be specified.

In an ADD FUNCTION clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function. For B-tree comparison functions and hash functions it is not necessary to specify *op_type* since the function's input data type(s) are always the correct ones to use. For B-tree sort support functions and all functions in GiST, SP-GiST and GIN operator classes, it is necessary to specify the operand data type(s) the function is to be used with.

In a DROP FUNCTION clause, the operand data type(s) the function is intended to support must be specified.

sort_family_name

The name (optionally schema-qualified) of an existing btree operator family that describes the sort ordering associated with an ordering operator.

If neither FOR SEARCH nor FOR ORDER BY is specified, FOR SEARCH is the default.

support_number

The index method's support procedure number for a function associated with the operator family.

function_name

The name (optionally schema-qualified) of a function that is an index method support procedure for the operator family.

argument_type

The parameter data type(s) of the function.

new_name

The new name of the operator family.

new_owner

The new owner of the operator family.

new_schema

The new schema for the operator family.

The OPERATOR and FUNCTION clauses can appear in any order.

Notes

Notice that the DROP syntax only specifies the "slot" in the operator family, by strategy or support number and input data type(s). The name of the operator or function occupying the slot is not men-

tioned. Also, for DROP FUNCTION the type(s) to specify are the input data type(s) the function is intended to support; for GiST, SP-GiST and GIN indexes this might have nothing to do with the actual input argument types of the function.

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator family is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator family.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before PostgreSQL 8.4, the OPERATOR clause could include a RECHECK option. This is no longer supported because whether an index operator is "lossy" is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command adds cross-data-type operators and support functions to an operator family that already contains B-tree operator classes for data types int4 and int2.

```
ALTER OPERATOR FAMILY integer_ops USING btree ADD

  -- int4 vs int2
  OPERATOR 1 < (int4, int2) ,
  OPERATOR 2 <= (int4, int2) ,
  OPERATOR 3 = (int4, int2) ,
  OPERATOR 4 >= (int4, int2) ,
  OPERATOR 5 > (int4, int2) ,
  FUNCTION 1 btint42cmp(int4, int2) ,

  -- int2 vs int4
  OPERATOR 1 < (int2, int4) ,
  OPERATOR 2 <= (int2, int4) ,
  OPERATOR 3 = (int2, int4) ,
  OPERATOR 4 >= (int2, int4) ,
  OPERATOR 5 > (int2, int4) ,
  FUNCTION 1 btint24cmp(int2, int4) ;
```

To remove these entries again:

```
ALTER OPERATOR FAMILY integer_ops USING btree DROP

  -- int4 vs int2
  OPERATOR 1 (int4, int2) ,
  OPERATOR 2 (int4, int2) ,
  OPERATOR 3 (int4, int2) ,
  OPERATOR 4 (int4, int2) ,
  OPERATOR 5 (int4, int2) ,
  FUNCTION 1 (int4, int2) ,

  -- int2 vs int4
  OPERATOR 1 (int2, int4) ,
  OPERATOR 2 (int2, int4) ,
  OPERATOR 3 (int2, int4) ,
  OPERATOR 4 (int2, int4) ,
```

```
OPERATOR 5 (int2, int4) ,
FUNCTION 1 (int2, int4) ;
```

Compatibility

There is no `ALTER OPERATOR FAMILY` statement in the SQL standard.

See Also

CREATE OPERATOR FAMILY, DROP OPERATOR FAMILY, CREATE OPERATOR CLASS, ALTER OPERATOR CLASS, DROP OPERATOR CLASS

ALTER ROLE

Name

ALTER ROLE — change a database role

Synopsis

```
ALTER ROLE name [ [ WITH ] option [ ... ] ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEUSER | NOCREATEUSER
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | CONNECTION LIMIT connlimit
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
    | VALID UNTIL 'timestamp'

ALTER ROLE name RENAME TO new_name

ALTER ROLE name [ IN DATABASE database_name ] SET configuration_parameter { TO | = } { value
ALTER ROLE { name | ALL } [ IN DATABASE database_name ] SET configuration_parameter FROM CUR
ALTER ROLE { name | ALL } [ IN DATABASE database_name ] RESET configuration_parameter
ALTER ROLE { name | ALL } [ IN DATABASE database_name ] RESET ALL
```

Description

ALTER ROLE changes the attributes of a PostgreSQL role.

The first variant of this command listed in the synopsis can change many of the role attributes that can be specified in CREATE ROLE. (All the possible attributes are covered, except that there are no options for adding or removing memberships; use GRANT and REVOKE for that.) Attributes not mentioned in the command retain their previous settings. Database superusers can change any of these settings for any role. Roles having CREATEROLE privilege can change any of these settings, but only for non-superuser and non-replication roles. Ordinary roles can only change their own password.

The second variant changes the name of the role. Database superusers can rename any role. Roles having CREATEROLE privilege can rename non-superuser roles. The current session user cannot be renamed. (Connect as a different user if you need to do that.) Because MD5-encrypted passwords use the role name as cryptographic salt, renaming a role clears its password if the password is MD5-encrypted.

The remaining variants change a role's session default for a configuration variable, either for all databases or, when the IN DATABASE clause is specified, only for sessions in the named database. If ALL is specified instead of a role name, this changes the setting for all roles. Using ALL with IN DATABASE is effectively the same as using the command ALTER DATABASE ... SET ....

Whenever the role subsequently starts a new session, the specified value becomes the session default, overriding whatever setting is present in `postgresql.conf` or has been received from the `postgres` command line. This only happens at login time; executing SET ROLE or SET SESSION AUTHORIZATION does not cause new configuration values to be set. Settings set for all databases are overridden by database-specific settings attached to a role. Settings for specific databases or specific roles override settings for all roles.

Superusers can change anyone's session defaults. Roles having `CREATEROLE` privilege can change defaults for non-superuser roles. Ordinary roles can only set defaults for themselves. Certain configuration variables cannot be set this way, or can only be set if a superuser issues the command. Only superusers can change a setting for all roles in all databases.

Parameters

name

The name of the role whose attributes are to be altered.

`SUPERUSER`
`NOSUPERUSER`
`CREATEDB`
`NOCREATEDB`
`CREATEROLE`
`NOCREATEROLE`
`CREATEUSER`
`NOCREATEUSER`
`INHERIT`
`NOINHERIT`
`LOGIN`
`NOLOGIN`
`REPLICATION`
`NOREPLICATION`
`CONNECTION LIMIT` *connlimit*
`PASSWORD` *password*
`ENCRYPTED`
`UNENCRYPTED`
`VALID UNTIL '`*timestamp*`'`

These clauses alter attributes originally set by CREATE ROLE. For more information, see the `CREATE ROLE` reference page.

new_name

The new name of the role.

database_name

The name of the database the configuration variable should be set in.

configuration_parameter
value

Set this role's session default for the specified configuration parameter to the given value. If *value* is `DEFAULT` or, equivalently, `RESET` is used, the role-specific variable setting is removed, so the role will inherit the system-wide default setting in new sessions. Use `RESET ALL` to clear all role-specific settings. `SET FROM CURRENT` saves the session's current value of the parameter

as the role-specific value. If `IN DATABASE` is specified, the configuration parameter is set or removed for the given role and database only.

Role-specific variable settings take effect only at login; SET ROLE and SET SESSION AUTHORIZATION do not process role-specific variable settings.

See SET and Chapter 18 for more information about allowed parameter names and values.

Notes

Use CREATE ROLE to add new roles, and DROP ROLE to remove a role.

`ALTER ROLE` cannot change a role's memberships. Use GRANT and REVOKE to do that.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. psql contains a command `\password` that can be used to change a role's password without exposing the cleartext password.

It is also possible to tie a session default to a specific database rather than to a role; see ALTER DATABASE. If there is a conflict, database-role-specific settings override role-specific ones, which in turn override database-specific ones.

Examples

Change a role's password:

```
ALTER ROLE davide WITH PASSWORD 'hu8jmn3';
```

Remove a role's password:

```
ALTER ROLE davide WITH PASSWORD NULL;
```

Change a password expiration date, specifying that the password should expire at midday on 4th May 2015 using the time zone which is one hour ahead of UTC:

```
ALTER ROLE chris VALID UNTIL 'May 4 12:00:00 2015 +1';
```

Make a password valid forever:

```
ALTER ROLE fred VALID UNTIL 'infinity';
```

Give a role the ability to create other roles and new databases:

```
ALTER ROLE miriam CREATEROLE CREATEDB;
```

Give a role a non-default setting of the maintenance_work_mem parameter:

```
ALTER ROLE worker_bee SET maintenance_work_mem = 100000;
```

Give a role a non-default, database-specific setting of the client_min_messages parameter:

```
ALTER ROLE fred IN DATABASE devel SET client_min_messages = DEBUG;
```

Compatibility

The `ALTER ROLE` statement is a PostgreSQL extension.

See Also

CREATE ROLE, DROP ROLE, ALTER DATABASE, SET

ALTER RULE

Name

ALTER RULE — change the definition of a rule

Synopsis

```
ALTER RULE name ON table_name RENAME TO new_name
```

Description

ALTER RULE changes properties of an existing rule. Currently, the only available action is to change the rule's name.

To use ALTER RULE, you must own the table or view that the rule applies to.

Parameters

name

The name of an existing rule to alter.

table_name

The name (optionally schema-qualified) of the table or view that the rule applies to.

new_name

The new name for the rule.

Examples

To rename an existing rule:

```
ALTER RULE notify_all ON emp RENAME TO notify_me;
```

Compatibility

ALTER RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

CREATE RULE, DROP RULE

ALTER SCHEMA

Name

ALTER SCHEMA — change the definition of a schema

Synopsis

```
ALTER SCHEMA name RENAME TO new_name
ALTER SCHEMA name OWNER TO new_owner
```

Description

ALTER SCHEMA changes the definition of a schema.

You must own the schema to use ALTER SCHEMA. To rename a schema you must also have the CREATE privilege for the database. To alter the owner, you must also be a direct or indirect member of the new owning role, and you must have the CREATE privilege for the database. (Note that superusers have all these privileges automatically.)

Parameters

name

The name of an existing schema.

new_name

The new name of the schema. The new name cannot begin with pg_, as such names are reserved for system schemas.

new_owner

The new owner of the schema.

Compatibility

There is no ALTER SCHEMA statement in the SQL standard.

See Also

CREATE SCHEMA, DROP SCHEMA

ALTER SEQUENCE

Name

ALTER SEQUENCE — change the definition of a sequence generator

Synopsis

```
ALTER SEQUENCE [ IF EXISTS ] name [ INCREMENT [ BY ] increment ]
    [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO MAXVALUE ]
    [ START [ WITH ] start ]
    [ RESTART [ [ WITH ] restart ] ]
    [ CACHE cache ] [ [ NO ] CYCLE ]
    [ OWNED BY { table_name.column_name | NONE } ]
ALTER SEQUENCE [ IF EXISTS ] name OWNER TO new_owner
ALTER SEQUENCE [ IF EXISTS ] name RENAME TO new_name
ALTER SEQUENCE [ IF EXISTS ] name SET SCHEMA new_schema
```

Description

ALTER SEQUENCE changes the parameters of an existing sequence generator. Any parameters not specifically set in the ALTER SEQUENCE command retain their prior settings.

You must own the sequence to use ALTER SEQUENCE. To change a sequence's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the sequence's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the sequence. However, a superuser can alter ownership of any sequence anyway.)

Parameters

name

The name (optionally schema-qualified) of a sequence to be altered.

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

increment

The clause INCREMENT BY *increment* is optional. A positive value will make an ascending sequence, a negative one a descending sequence. If unspecified, the old increment value will be maintained.

minvalue
NO MINVALUE

The optional clause MINVALUE *minvalue* determines the minimum value a sequence can generate. If NO MINVALUE is specified, the defaults of 1 and -2^{63}-1 for ascending and descending sequences, respectively, will be used. If neither option is specified, the current minimum value will be maintained.

maxvalue
NO MAXVALUE

The optional clause MAXVALUE *maxvalue* determines the maximum value for the sequence. If NO MAXVALUE is specified, the defaults are 2^{63}-1 and -1 for ascending and descending sequences, respectively, will be used. If neither option is specified, the current maximum value will be maintained.

start

The optional clause START WITH *start* changes the recorded start value of the sequence. This has no effect on the *current* sequence value; it simply sets the value that future ALTER SEQUENCE RESTART commands will use.

restart

The optional clause RESTART [WITH *restart*] changes the current value of the sequence. This is equivalent to calling the setval function with is_called = false: the specified value will be returned by the *next* call of nextval. Writing RESTART with no *restart* value is equivalent to supplying the start value that was recorded by CREATE SEQUENCE or last set by ALTER SEQUENCE START WITH.

cache

The clause CACHE *cache* enables sequence numbers to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache). If unspecified, the old cache value will be maintained.

CYCLE

The optional CYCLE key word can be used to enable the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

NO CYCLE

If the optional NO CYCLE key word is specified, any calls to nextval after the sequence has reached its maximum value will return an error. If neither CYCLE or NO CYCLE are specified, the old cycle behavior will be maintained.

OWNED BY *table_name.column_name*
OWNED BY NONE

The OWNED BY option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. If specified, this association replaces any previously specified association for the sequence. The specified table must have the same owner and be in the same schema as the sequence. Specifying OWNED BY NONE removes any existing association, making the sequence “free-standing”.

new_owner

The user name of the new owner of the sequence.

new_name

The new name for the sequence.

new_schema

The new schema for the sequence.

Notes

To avoid blocking of concurrent transactions that obtain numbers from the same sequence, ALTER SEQUENCE's effects on the sequence generation parameters are never rolled back; those changes take effect immediately and are not reversible. However, the OWNED BY, OWNER TO, RENAME TO, and SET SCHEMA clauses cause ordinary catalog updates that can be rolled back.

ALTER SEQUENCE will not immediately affect nextval results in backends, other than the current one, that have preallocated (cached) sequence values. They will use up all cached values prior to noticing the changed sequence generation parameters. The current backend will be affected immediately.

ALTER SEQUENCE does not affect the currval status for the sequence. (Before PostgreSQL 8.3, it sometimes did.)

For historical reasons, ALTER TABLE can be used with sequences too; but the only variants of ALTER TABLE that are allowed with sequences are equivalent to the forms shown above.

Examples

Restart a sequence called serial, at 105:

```
ALTER SEQUENCE serial RESTART WITH 105;
```

Compatibility

ALTER SEQUENCE conforms to the SQL standard, except for the START WITH, OWNED BY, OWNER TO, RENAME TO, and SET SCHEMA clauses, which are PostgreSQL extensions.

See Also

CREATE SEQUENCE, DROP SEQUENCE

ALTER SERVER

Name

ALTER SERVER — change the definition of a foreign server

Synopsis

```
ALTER SERVER name [ VERSION 'new_version' ]
    [ OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] ) ]
ALTER SERVER name OWNER TO new_owner
ALTER SERVER name RENAME TO new_name
```

Description

ALTER SERVER changes the definition of a foreign server. The first form changes the server version string or the generic options of the server (at least one clause is required). The second form changes the owner of the server.

To alter the server you must be the owner of the server. Additionally to alter the owner, you must own the server and also be a direct or indirect member of the new owning role, and you must have USAGE privilege on the server's foreign-data wrapper. (Note that superusers satisfy all these criteria automatically.)

Parameters

name

The name of an existing server.

new_version

New server version.

OPTIONS ([ADD | SET | DROP] *option* ['*value*'] [, ...])

Change options for the server. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; names and values are also validated using the server's foreign-data wrapper library.

new_owner

The user name of the new owner of the foreign server.

new_name

The new name for the foreign server.

Examples

Alter server foo, add connection options:

```
ALTER SERVER foo OPTIONS (host 'foo', dbname 'foodb');
```

Alter server `foo`, change version, change `host` option:

```
ALTER SERVER foo VERSION '8.4' OPTIONS (SET host 'baz');
```

Compatibility

`ALTER SERVER` conforms to ISO/IEC 9075-9 (SQL/MED). The `OWNER TO` and `RENAME` forms are PostgreSQL extensions.

See Also

CREATE SERVER, DROP SERVER

ALTER SYSTEM

Name

ALTER SYSTEM — change a server configuration parameter

Synopsis

```
ALTER SYSTEM SET configuration_parameter { TO | = } { value | 'value' | DEFAULT }

ALTER SYSTEM RESET configuration_parameter
ALTER SYSTEM RESET ALL
```

Description

ALTER SYSTEM is used for changing server configuration parameters across the entire database cluster. It can be more convenient than the traditional method of manually editing the postgresql.conf file. ALTER SYSTEM writes the given parameter setting to the postgresql.auto.conf file, which is read in addition to postgresql.conf. Setting a parameter to DEFAULT, or using the RESET variant, removes that configuration entry from the postgresql.auto.conf file. Use RESET ALL to remove all such configuration entries.

Values set with ALTER SYSTEM will be effective after the next server configuration reload (SIGHUP or pg_ctl reload), or after the next server restart in the case of parameters that can only be changed at server start.

Only superusers can use ALTER SYSTEM. Also, since this command acts directly on the file system and cannot be rolled back, it is not allowed inside a transaction block or function.

Parameters

configuration_parameter

Name of a settable configuration parameter. Available parameters are documented in Chapter 18.

value

New value of the parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. DEFAULT can be written to specify removing the parameter and its value from postgresql.auto.conf.

Notes

This command can't be used to set data_directory, nor parameters that are not allowed in postgresql.conf (e.g., preset options).

See Section 18.1 for other ways to set the parameters.

Examples

Set the `wal_level`:

```
ALTER SYSTEM SET wal_level = hot_standby;
```

Undo that, restoring whatever setting was effective in `postgresql.conf`:

```
ALTER SYSTEM RESET wal_level;
```

Compatibility

The `ALTER SYSTEM` statement is a PostgreSQL extension.

See Also

SET, SHOW

ALTER TABLE

Name

ALTER TABLE — change the definition of a table

Synopsis

```
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    action [, ... ]
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME [ COLUMN ] column_name TO new_column_name
ALTER TABLE [ IF EXISTS ] [ ONLY ] name [ * ]
    RENAME CONSTRAINT constraint_name TO new_constraint_name
ALTER TABLE [ IF EXISTS ] name
    RENAME TO new_name
ALTER TABLE [ IF EXISTS ] name
    SET SCHEMA new_schema
ALTER TABLE ALL IN TABLESPACE name [ OWNED BY role_name [, ... ] ]
    SET TABLESPACE new_tablespace [ NOWAIT ]

where action is one of:

    ADD [ COLUMN ] column_name data_type [ COLLATE collation ] [ column_constraint [ ... ] ]
    DROP [ COLUMN ] [ IF EXISTS ] column_name [ RESTRICT | CASCADE ]
    ALTER [ COLUMN ] column_name [ SET DATA ] TYPE data_type [ COLLATE collation ] [ USING
    ALTER [ COLUMN ] column_name SET DEFAULT expression
    ALTER [ COLUMN ] column_name DROP DEFAULT
    ALTER [ COLUMN ] column_name { SET | DROP } NOT NULL
    ALTER [ COLUMN ] column_name SET STATISTICS integer
    ALTER [ COLUMN ] column_name SET ( attribute_option = value [, ... ] )
    ALTER [ COLUMN ] column_name RESET ( attribute_option [, ... ] )
    ALTER [ COLUMN ] column_name SET STORAGE { PLAIN | EXTERNAL | EXTENDED | MAIN }
    ADD table_constraint [ NOT VALID ]
    ADD table_constraint_using_index
    ALTER CONSTRAINT constraint_name [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED
    VALIDATE CONSTRAINT constraint_name
    DROP CONSTRAINT [ IF EXISTS ]  constraint_name [ RESTRICT | CASCADE ]
    DISABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE TRIGGER [ trigger_name | ALL | USER ]
    ENABLE REPLICA TRIGGER trigger_name
    ENABLE ALWAYS TRIGGER trigger_name
    DISABLE RULE rewrite_rule_name
    ENABLE RULE rewrite_rule_name
    ENABLE REPLICA RULE rewrite_rule_name
    ENABLE ALWAYS RULE rewrite_rule_name
    CLUSTER ON index_name
    SET WITHOUT CLUSTER
    SET WITH OIDS
    SET WITHOUT OIDS
    SET ( storage_parameter = value [, ... ] )
    RESET ( storage_parameter [, ... ] )
    INHERIT parent_table
    NO INHERIT parent_table
    OF type_name
```

```
    NOT OF
    OWNER TO new_owner
    SET TABLESPACE new_tablespace
    REPLICA IDENTITY {DEFAULT | USING INDEX index_name | FULL | NOTHING}
```

and *table_constraint_using_index* is:

```
    [ CONSTRAINT constraint_name ]
    { UNIQUE | PRIMARY KEY } USING INDEX index_name
    [ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]
```

Description

`ALTER TABLE` changes the definition of an existing table. There are several subforms described below. Note that the lock level required may differ for each subform. An `ACCESS EXCLUSIVE` lock is held unless explicitly noted. When multiple subcommands are listed, the lock held will be the strictest one required from any subcommand.

`ADD COLUMN`

This form adds a new column to the table, using the same syntax as CREATE TABLE.

`DROP COLUMN [ IF EXISTS ]`

This form drops a column from a table. Indexes and table constraints involving the column will be automatically dropped as well. You will need to say `CASCADE` if anything outside the table depends on the column, for example, foreign key references or views. If `IF EXISTS` is specified and the column does not exist, no error is thrown. In this case a notice is issued instead.

`IF EXISTS`

Do not throw an error if the table does not exist. A notice is issued in this case.

`SET DATA TYPE`

This form changes the type of a column of a table. Indexes and simple table constraints involving the column will be automatically converted to use the new column type by reparsing the originally supplied expression. The optional `COLLATE` clause specifies a collation for the new column; if omitted, the collation is the default for the new column type. The optional `USING` clause specifies how to compute the new column value from the old; if omitted, the default conversion is the same as an assignment cast from old data type to new. A `USING` clause must be provided if there is no implicit or assignment cast from old to new type.

`SET/DROP DEFAULT`

These forms set or remove the default value for a column. Default values only apply in subsequent `INSERT` or `UPDATE` commands; they do not cause rows already in the table to change.

`SET/DROP NOT NULL`

These forms change whether a column is marked to allow null values or to reject null values. You can only use `SET NOT NULL` when the column contains no null values.

`SET STATISTICS`

This form sets the per-column statistics-gathering target for subsequent ANALYZE operations. The target can be set in the range 0 to 10000; alternatively, set it to -1 to revert to using the system default statistics target (default_statistics_target). For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

SET STATISTICS acquires a SHARE UPDATE EXCLUSIVE lock.

SET (*attribute_option* = *value* [, ...])
RESET (*attribute_option* [, ...])

This form sets or resets per-attribute options. Currently, the only defined per-attribute options are n_distinct and n_distinct_inherited, which override the number-of-distinct-values estimates made by subsequent ANALYZE operations. n_distinct affects the statistics for the table itself, while n_distinct_inherited affects the statistics gathered for the table plus its inheritance children. When set to a positive value, ANALYZE will assume that the column contains exactly the specified number of distinct nonnull values. When set to a negative value, which must be greater than or equal to -1, ANALYZE will assume that the number of distinct nonnull values in the column is linear in the size of the table; the exact count is to be computed by multiplying the estimated table size by the absolute value of the given number. For example, a value of -1 implies that all values in the column are distinct, while a value of -0.5 implies that each value appears twice on the average. This can be useful when the size of the table changes over time, since the multiplication by the number of rows in the table is not performed until query planning time. Specify a value of 0 to revert to estimating the number of distinct values normally. For more information on the use of statistics by the PostgreSQL query planner, refer to Section 14.2.

Changing per-attribute options acquires a SHARE UPDATE EXCLUSIVE lock.

SET STORAGE

This form sets the storage mode for a column. This controls whether this column is held inline or in a secondary TOAST table, and whether the data should be compressed or not. PLAIN must be used for fixed-length values such as integer and is inline, uncompressed. MAIN is for inline, compressible data. EXTERNAL is for external, uncompressed data, and EXTENDED is for external, compressed data. EXTENDED is the default for most data types that support non-PLAIN storage. Use of EXTERNAL will make substring operations on very large text and bytea values run faster, at the penalty of increased storage space. Note that SET STORAGE doesn't itself change anything in the table, it just sets the strategy to be pursued during future table updates. See Section 59.2 for more information.

ADD *table_constraint* [NOT VALID]

This form adds a new constraint to a table using the same syntax as CREATE TABLE, plus the option NOT VALID, which is currently only allowed for foreign key and CHECK constraints. If the constraint is marked NOT VALID, the potentially-lengthy initial check to verify that all rows in the table satisfy the constraint is skipped. The constraint will still be enforced against subsequent inserts or updates (that is, they'll fail unless there is a matching row in the referenced table, in the case of foreign keys; and they'll fail unless the new row matches the specified check constraints). But the database will not assume that the constraint holds for all rows in the table, until it is validated by using the VALIDATE CONSTRAINT option.

ADD *table_constraint_using_index*

This form adds a new PRIMARY KEY or UNIQUE constraint to a table based on an existing unique index. All the columns of the index will be included in the constraint.

The index cannot have expression columns nor be a partial index. Also, it must be a b-tree index with default sort ordering. These restrictions ensure that the index is equivalent to one that would be built by a regular ADD PRIMARY KEY or ADD UNIQUE command.

If PRIMARY KEY is specified, and the index's columns are not already marked NOT NULL, then this command will attempt to do ALTER COLUMN SET NOT NULL against each such column. That requires a full table scan to verify the column(s) contain no nulls. In all other cases, this is a fast operation.

If a constraint name is provided then the index will be renamed to match the constraint name. Otherwise the constraint will be named the same as the index.

After this command is executed, the index is "owned" by the constraint, in the same way as if the index had been built by a regular `ADD PRIMARY KEY` or `ADD UNIQUE` command. In particular, dropping the constraint will make the index disappear too.

> **Note:** Adding a constraint using an existing index can be helpful in situations where a new constraint needs to be added without blocking table updates for a long time. To do that, create the index using `CREATE INDEX CONCURRENTLY`, and then install it as an official constraint using this syntax. See the example below.

`ALTER CONSTRAINT`

This form alters the attributes of a constraint that was previously created. Currently only foreign key constraints may be altered.

`VALIDATE CONSTRAINT`

This form validates a foreign key or check constraint that was previously created as `NOT VALID`, by scanning the table to ensure there are no rows for which the constraint is not satisfied. Nothing happens if the constraint is already marked valid.

Validation can be a long process on larger tables. The value of separating validation from initial creation is that you can defer validation to less busy times, or can be used to give additional time to correct pre-existing errors while preventing new errors. Note also that validation on its own does not prevent normal write commands against the table while it runs.

Validation acquires only a `SHARE UPDATE EXCLUSIVE` lock on the table being altered. If the constraint is a foreign key then a `ROW SHARE` lock is also required on the table referenced by the constraint.

`DROP CONSTRAINT [ IF EXISTS ]`

This form drops the specified constraint on a table. If `IF EXISTS` is specified and the constraint does not exist, no error is thrown. In this case a notice is issued instead.

`DISABLE/ENABLE [ REPLICA | ALWAYS ] TRIGGER`

These forms configure the firing of trigger(s) belonging to the table. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. For a deferred trigger, the enable status is checked when the event occurs, not when the trigger function is actually executed. One can disable or enable a single trigger specified by name, or all triggers on the table, or only user triggers (this option excludes internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints). Disabling or enabling internally generated constraint triggers requires superuser privileges; it should be done with caution since of course the integrity of the constraint cannot be guaranteed if the triggers are not executed. The trigger firing mechanism is also affected by the configuration variable session_replication_role. Simply enabled triggers will fire when the replication role is "origin" (the default) or "local". Triggers configured as `ENABLE REPLICA` will only fire if the session is in "replica" mode, and triggers configured as `ENABLE ALWAYS` will fire regardless of the current replication mode.

`DISABLE/ENABLE [ REPLICA | ALWAYS ] RULE`

These forms configure the firing of rewrite rules belonging to the table. A disabled rule is still known to the system, but is not applied during query rewriting. The semantics are as for disabled/enabled triggers. This configuration is ignored for `ON SELECT` rules, which are always

applied in order to keep views working even if the current session is in a non-default replication role.

`CLUSTER ON`

This form selects the default index for future CLUSTER operations. It does not actually re-cluster the table.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

`SET WITHOUT CLUSTER`

This form removes the most recently used CLUSTER index specification from the table. This affects future cluster operations that don't specify an index.

Changing cluster options acquires a `SHARE UPDATE EXCLUSIVE` lock.

`SET WITH OIDS`

This form adds an `oid` system column to the table (see Section 5.4). It does nothing if the table already has OIDs.

Note that this is not equivalent to `ADD COLUMN oid oid`; that would add a normal column that happened to be named `oid`, not a system column.

`SET WITHOUT OIDS`

This form removes the `oid` system column from the table. This is exactly equivalent to `DROP COLUMN oid RESTRICT`, except that it will not complain if there is already no `oid` column.

`SET ( storage_parameter = value [, ... ] )`

This form changes one or more storage parameters for the table. See *Storage Parameters* for details on the available parameters. Note that the table contents will not be modified immediately by this command; depending on the parameter you might need to rewrite the table to get the desired effects. That can be done with VACUUM FULL, CLUSTER or one of the forms of `ALTER TABLE` that forces a table rewrite.

> **Note:** While `CREATE TABLE` allows `OIDS` to be specified in the `WITH (storage_parameter)` syntax, `ALTER TABLE` does not treat `OIDS` as a storage parameter. Instead use the `SET WITH OIDS` and `SET WITHOUT OIDS` forms to change OID status.

`RESET ( storage_parameter [, ... ] )`

This form resets one or more storage parameters to their defaults. As with `SET`, a table rewrite might be needed to update the table entirely.

`INHERIT parent_table`

This form adds the target table as a new child of the specified parent table. Subsequently, queries against the parent will include records of the target table. To be added as a child, the target table must already contain all the same columns as the parent (it could have additional columns, too). The columns must have matching data types, and if they have `NOT NULL` constraints in the parent then they must also have `NOT NULL` constraints in the child.

There must also be matching child-table constraints for all `CHECK` constraints of the parent, except those marked non-inheritable (that is, created with `ALTER TABLE ... ADD CONSTRAINT ... NO INHERIT`) in the parent, which are ignored; all child-table constraints matched must not be marked non-inheritable. Currently `UNIQUE`, `PRIMARY KEY`, and `FOREIGN KEY` constraints are not considered, but this might change in the future.

`NO INHERIT` *parent_table*

This form removes the target table from the list of children of the specified parent table. Queries against the parent table will no longer include records drawn from the target table.

`OF` *type_name*

This form links the table to a composite type as though `CREATE TABLE OF` had formed it. The table's list of column names and types must precisely match that of the composite type; the presence of an `oid` system column is permitted to differ. The table must not inherit from any other table. These restrictions ensure that `CREATE TABLE OF` would permit an equivalent table definition.

`NOT OF`

This form dissociates a typed table from its type.

`OWNER`

This form changes the owner of the table, sequence, view, materialized view, or foreign table to the specified user.

`SET TABLESPACE`

This form changes the table's tablespace to the specified tablespace and moves the data file(s) associated with the table to the new tablespace. Indexes on the table, if any, are not moved; but they can be moved separately with additional `SET TABLESPACE` commands. All tables in the current database in a tablespace can be moved by using the `ALL IN TABLESPACE` form, which will lock all tables to be moved first and then move each one. This form also supports `OWNED BY`, which will only move tables owned by the roles specified. If the `NOWAIT` option is specified then the command will fail if it is unable to acquire all of the locks required immediately. Note that system catalogs are not moved by this command, use `ALTER DATABASE` or explicit `ALTER TABLE` invocations instead if desired. The `information_schema` relations are not considered part of the system catalogs and will be moved. See also CREATE TABLESPACE.

`REPLICA IDENTITY`

This form changes the information which is written to the write-ahead log to identify rows which are updated or deleted. This option has no effect except when logical replication is in use. `DEFAULT` (the default for non-system tables) records the old values of the columns of the primary key, if any. `USING INDEX` records the old values of the columns covered by the named index, which must be unique, not partial, not deferrable, and include only columns marked `NOT NULL`. `FULL` records the old values of all columns in the row. `NOTHING` records no information about the old row. (This is the default for system tables.) In all cases, no old values are logged unless at least one of the columns that would be logged differs between the old and new versions of the row.

`RENAME`

The `RENAME` forms change the name of a table (or an index, sequence, view, materialized view, or foreign table), the name of an individual column in a table, or the name of a constraint of the table. There is no effect on the stored data.

`SET SCHEMA`

This form moves the table into another schema. Associated indexes, constraints, and sequences owned by table columns are moved as well.

All the actions except `RENAME`, `SET TABLESPACE` and `SET SCHEMA` can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several columns and/or alter

the type of several columns in a single command. This is particularly useful with large tables, since only one pass over the table need be made.

You must own the table to use ALTER TABLE. To change the schema or tablespace of a table, you must also have CREATE privilege on the new schema or tablespace. To add the table as a new child of a parent table, you must own the parent table as well. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the table's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the table. However, a superuser can alter ownership of any table anyway.) To add a column or alter a column type or use the OF clause, you must also have USAGE privilege on the data type.

Parameters

name

The name (optionally schema-qualified) of an existing table to alter. If ONLY is specified before the table name, only that table is altered. If ONLY is not specified, the table and all its descendant tables (if any) are altered. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

column_name

Name of a new or existing column.

new_column_name

New name for an existing column.

new_name

New name for the table.

data_type

Data type of the new column, or new data type for an existing column.

table_constraint

New table constraint for the table.

constraint_name

Name of a new or existing constraint.

CASCADE

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column).

RESTRICT

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

trigger_name

Name of a single trigger to disable or enable.

ALL

Disable or enable all triggers belonging to the table. (This requires superuser privilege if any of the triggers are internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.)

`USER`

Disable or enable all triggers belonging to the table except for internally generated constraint triggers such as those that are used to implement foreign key constraints or deferrable uniqueness and exclusion constraints.

`index_name`

The name of an existing index.

`storage_parameter`

The name of a table storage parameter.

`value`

The new value for a table storage parameter. This might be a number or a word depending on the parameter.

`parent_table`

A parent table to associate or de-associate with this table.

`new_owner`

The user name of the new owner of the table.

`new_tablespace`

The name of the tablespace to which the table will be moved.

`new_schema`

The name of the schema to which the table will be moved.

Notes

The key word `COLUMN` is noise and can be omitted.

When a column is added with `ADD COLUMN`, all existing rows in the table are initialized with the column's default value (NULL if no `DEFAULT` clause is specified). If there is no `DEFAULT` clause, this is merely a metadata change and does not require any immediate update of the table's data; the added NULL values are supplied on readout, instead.

Adding a column with a `DEFAULT` clause or changing the type of an existing column will require the entire table and its indexes to be rewritten. As an exception when changing the type of an existing column, if the `USING` clause does not change the column contents and the old type is either binary coercible to the new type or an unconstrained domain over the new type, a table rewrite is not needed; but any indexes on the affected columns must still be rebuilt. Adding or removing a system `oid` column also requires rewriting the entire table. Table and/or index rebuilds may take a significant amount of time for a large table; and will temporarily require as much as double the disk space.

Adding a `CHECK` or `NOT NULL` constraint requires scanning the table to verify that existing rows meet the constraint.

The main reason for providing the option to specify multiple changes in a single `ALTER TABLE` is that multiple table scans or rewrites can thereby be combined into a single pass over the table.

The `DROP COLUMN` form does not physically remove the column, but simply makes it invisible to SQL operations. Subsequent insert and update operations in the table will store a null value for the column. Thus, dropping a column is quick but it will not immediately reduce the on-disk size of your table, as the space occupied by the dropped column is not reclaimed. The space will be reclaimed over time

as existing rows are updated. (These statements do not apply when dropping the system `oid` column; that is done with an immediate rewrite.)

To force an immediate rewrite of the table, you can use VACUUM FULL, CLUSTER or one of the forms of ALTER TABLE that forces a rewrite. This results in no semantically-visible change in the table, but gets rid of no-longer-useful data.

The `USING` option of `SET DATA TYPE` can actually specify any expression involving the old values of the row; that is, it can refer to other columns as well as the one being converted. This allows very general conversions to be done with the `SET DATA TYPE` syntax. Because of this flexibility, the `USING` expression is not applied to the column's default value (if any); the result might not be a constant expression as required for a default. This means that when there is no implicit or assignment cast from old to new type, `SET DATA TYPE` might fail to convert the default even though a `USING` clause is supplied. In such cases, drop the default with `DROP DEFAULT`, perform the `ALTER TYPE`, and then use `SET DEFAULT` to add a suitable new default. Similar considerations apply to indexes and constraints involving the column.

If a table has any descendant tables, it is not permitted to add, rename, or change the type of a column, or rename an inherited constraint in the parent table without doing the same to the descendants. That is, `ALTER TABLE ONLY` will be rejected. This ensures that the descendants always have columns matching the parent.

A recursive `DROP COLUMN` operation will remove a descendant table's column only if the descendant does not inherit that column from any other parents and never had an independent definition of the column. A nonrecursive `DROP COLUMN` (i.e., `ALTER TABLE ONLY ... DROP COLUMN`) never removes any descendant columns, but instead marks them as independently defined rather than inherited.

The `TRIGGER`, `CLUSTER`, `OWNER`, and `TABLESPACE` actions never recurse to descendant tables; that is, they always act as though `ONLY` were specified. Adding a constraint recurses only for `CHECK` constraints that are not marked `NO INHERIT`.

Changing any part of a system catalog table is not permitted.

Refer to CREATE TABLE for a further description of valid parameters. Chapter 5 has further information on inheritance.

Examples

To add a column of type `varchar` to a table:

```
ALTER TABLE distributors ADD COLUMN address varchar(30);
```

To drop a column from a table:

```
ALTER TABLE distributors DROP COLUMN address RESTRICT;
```

To change the types of two existing columns in one operation:

```
ALTER TABLE distributors
    ALTER COLUMN address TYPE varchar(80),
    ALTER COLUMN name TYPE varchar(100);
```

To change an integer column containing UNIX timestamps to `timestamp with time zone` via a `USING` clause:

```
ALTER TABLE foo
    ALTER COLUMN foo_timestamp SET DATA TYPE timestamp with time zone
    USING
        timestamp with time zone 'epoch' + foo_timestamp * interval '1 second';
```

The same, when the column has a default expression that won't automatically cast to the new data type:

```
ALTER TABLE foo
    ALTER COLUMN foo_timestamp DROP DEFAULT,
    ALTER COLUMN foo_timestamp TYPE timestamp with time zone
    USING
        timestamp with time zone 'epoch' + foo_timestamp * interval '1 second',
    ALTER COLUMN foo_timestamp SET DEFAULT now();
```

To rename an existing column:

```
ALTER TABLE distributors RENAME COLUMN address TO city;
```

To rename an existing table:

```
ALTER TABLE distributors RENAME TO suppliers;
```

To rename an existing constraint:

```
ALTER TABLE distributors RENAME CONSTRAINT zipchk TO zip_check;
```

To add a not-null constraint to a column:

```
ALTER TABLE distributors ALTER COLUMN street SET NOT NULL;
```

To remove a not-null constraint from a column:

```
ALTER TABLE distributors ALTER COLUMN street DROP NOT NULL;
```

To add a check constraint to a table and all its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK (char_length(zipcode) = 5);
```

To add a check constraint only to a table and not to its children:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK (char_length(zipcode) = 5) NO INHER
```

(The check constraint will not be inherited by future children, either.)

To remove a check constraint from a table and all its children:

```
ALTER TABLE distributors DROP CONSTRAINT zipchk;
```

To remove a check constraint from one table only:

```
ALTER TABLE ONLY distributors DROP CONSTRAINT zipchk;
```

(The check constraint remains in place for any child tables.)

To add a foreign key constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY (address) REFERENCES addresse
```

To add a foreign key constraint to a table with the least impact on other work:

```
ALTER TABLE distributors ADD CONSTRAINT distfk FOREIGN KEY (address) REFERENCES addresse
ALTER TABLE distributors VALIDATE CONSTRAINT distfk;
```

To add a (multicolumn) unique constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT dist_id_zipcode_key UNIQUE (dist_id, zipcode);
```

To add an automatically named primary key constraint to a table, noting that a table can only ever have one primary key:

```
ALTER TABLE distributors ADD PRIMARY KEY (dist_id);
```

To move a table to a different tablespace:

```
ALTER TABLE distributors SET TABLESPACE fasttablespace;
```

To move a table to a different schema:

```
ALTER TABLE myschema.distributors SET SCHEMA yourschema;
```

To recreate a primary key constraint, without blocking updates while the index is rebuilt:

```
CREATE UNIQUE INDEX CONCURRENTLY dist_id_temp_idx ON distributors (dist_id);
ALTER TABLE distributors DROP CONSTRAINT distributors_pkey,
    ADD CONSTRAINT distributors_pkey PRIMARY KEY USING INDEX dist_id_temp_idx;
```

Compatibility

The forms `ADD` (without `USING INDEX`), `DROP`, `SET DEFAULT`, and `SET DATA TYPE` (without `USING`) conform with the SQL standard. The other forms are PostgreSQL extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER TABLE` command is an extension.

`ALTER TABLE DROP COLUMN` can be used to drop the only column of a table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column tables.

See Also

CREATE TABLE

ALTER TABLESPACE

Name

ALTER TABLESPACE — change the definition of a tablespace

Synopsis

```
ALTER TABLESPACE name RENAME TO new_name
ALTER TABLESPACE name OWNER TO new_owner
ALTER TABLESPACE name SET ( tablespace_option = value [, ... ] )
ALTER TABLESPACE name RESET ( tablespace_option [, ... ] )
```

Description

ALTER TABLESPACE can be used to change the definition of a tablespace.

You must own the tablespace to change the definition of a tablespace. To alter the owner, you must also be a direct or indirect member of the new owning role. (Note that superusers have these privileges automatically.)

Parameters

name

The name of an existing tablespace.

new_name

The new name of the tablespace. The new name cannot begin with pg_, as such names are reserved for system tablespaces.

new_owner

The new owner of the tablespace.

tablespace_option

A tablespace parameter to be set or reset. Currently, the only available parameters are seq_page_cost and random_page_cost. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same name (see seq_page_cost, random_page_cost). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Examples

Rename tablespace index_space to fast_raid:

```
ALTER TABLESPACE index_space RENAME TO fast_raid;
```

Change the owner of tablespace `index_space`:

```
ALTER TABLESPACE index_space OWNER TO mary;
```

Compatibility

There is no `ALTER TABLESPACE` statement in the SQL standard.

See Also

CREATE TABLESPACE, DROP TABLESPACE

ALTER TEXT SEARCH CONFIGURATION

Name

ALTER TEXT SEARCH CONFIGURATION — change the definition of a text search configuration

Synopsis

```
ALTER TEXT SEARCH CONFIGURATION name
    ADD MAPPING FOR token_type [, ... ] WITH dictionary_name [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] WITH dictionary_name [, ... ]
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING REPLACE old_dictionary WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    ALTER MAPPING FOR token_type [, ... ] REPLACE old_dictionary WITH new_dictionary
ALTER TEXT SEARCH CONFIGURATION name
    DROP MAPPING [ IF EXISTS ] FOR token_type [, ... ]
ALTER TEXT SEARCH CONFIGURATION name RENAME TO new_name
ALTER TEXT SEARCH CONFIGURATION name OWNER TO new_owner
ALTER TEXT SEARCH CONFIGURATION name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH CONFIGURATION changes the definition of a text search configuration. You can modify its mappings from token types to dictionaries, or change the configuration's name or owner.

You must be the owner of the configuration to use ALTER TEXT SEARCH CONFIGURATION.

Parameters

name

The name (optionally schema-qualified) of an existing text search configuration.

token_type

The name of a token type that is emitted by the configuration's parser.

dictionary_name

The name of a text search dictionary to be consulted for the specified token type(s). If multiple dictionaries are listed, they are consulted in the specified order.

old_dictionary

The name of a text search dictionary to be replaced in the mapping.

new_dictionary

The name of a text search dictionary to be substituted for *old_dictionary*.

new_name

The new name of the text search configuration.

new_owner

The new owner of the text search configuration.

new_schema

The new schema for the text search configuration.

The `ADD MAPPING FOR` form installs a list of dictionaries to be consulted for the specified token type(s); it is an error if there is already a mapping for any of the token types. The `ALTER MAPPING FOR` form does the same, but first removing any existing mapping for those token types. The `ALTER MAPPING REPLACE` forms substitute *new_dictionary* for *old_dictionary* anywhere the latter appears. This is done for only the specified token types when `FOR` appears, or for all mappings of the configuration when it doesn't. The `DROP MAPPING` form removes all dictionaries for the specified token type(s), causing tokens of those types to be ignored by the text search configuration. It is an error if there is no mapping for the token types, unless `IF EXISTS` appears.

Examples

The following example replaces the `english` dictionary with the `swedish` dictionary anywhere that `english` is used within `my_config`.

```
ALTER TEXT SEARCH CONFIGURATION my_config
  ALTER MAPPING REPLACE english WITH swedish;
```

Compatibility

There is no `ALTER TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

CREATE TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

ALTER TEXT SEARCH DICTIONARY

Name

ALTER TEXT SEARCH DICTIONARY — change the definition of a text search dictionary

Synopsis

```
ALTER TEXT SEARCH DICTIONARY name (
    option [ = value ] [, ... ]
)
ALTER TEXT SEARCH DICTIONARY name RENAME TO new_name
ALTER TEXT SEARCH DICTIONARY name OWNER TO new_owner
ALTER TEXT SEARCH DICTIONARY name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH DICTIONARY changes the definition of a text search dictionary. You can change the dictionary's template-specific options, or change the dictionary's name or owner.

You must be the owner of the dictionary to use ALTER TEXT SEARCH DICTIONARY.

Parameters

name

The name (optionally schema-qualified) of an existing text search dictionary.

option

The name of a template-specific option to be set for this dictionary.

value

The new value to use for a template-specific option. If the equal sign and value are omitted, then any previous setting for the option is removed from the dictionary, allowing the default to be used.

new_name

The new name of the text search dictionary.

new_owner

The new owner of the text search dictionary.

new_schema

The new schema for the text search dictionary.

Template-specific options can appear in any order.

Examples

The following example command changes the stopword list for a Snowball-based dictionary. Other parameters remain unchanged.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( StopWords = newrussian );
```

The following example command changes the language option to `dutch`, and removes the stopword option entirely.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( language = dutch, StopWords );
```

The following example command "updates" the dictionary's definition without actually changing anything.

```
ALTER TEXT SEARCH DICTIONARY my_dict ( dummy );
```

(The reason this works is that the option removal code doesn't complain if there is no such option.) This trick is useful when changing configuration files for the dictionary: the `ALTER` will force existing database sessions to re-read the configuration files, which otherwise they would never do if they had read them earlier.

Compatibility

There is no `ALTER TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

CREATE TEXT SEARCH DICTIONARY, DROP TEXT SEARCH DICTIONARY

ALTER TEXT SEARCH PARSER

Name

ALTER TEXT SEARCH PARSER — change the definition of a text search parser

Synopsis

```
ALTER TEXT SEARCH PARSER name RENAME TO new_name
ALTER TEXT SEARCH PARSER name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH PARSER changes the definition of a text search parser. Currently, the only supported functionality is to change the parser's name.

You must be a superuser to use ALTER TEXT SEARCH PARSER.

Parameters

name

The name (optionally schema-qualified) of an existing text search parser.

new_name

The new name of the text search parser.

new_schema

The new schema for the text search parser.

Compatibility

There is no ALTER TEXT SEARCH PARSER statement in the SQL standard.

See Also

CREATE TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER

ALTER TEXT SEARCH TEMPLATE

Name

ALTER TEXT SEARCH TEMPLATE — change the definition of a text search template

Synopsis

```
ALTER TEXT SEARCH TEMPLATE name RENAME TO new_name
ALTER TEXT SEARCH TEMPLATE name SET SCHEMA new_schema
```

Description

ALTER TEXT SEARCH TEMPLATE changes the definition of a text search template. Currently, the only supported functionality is to change the template's name.

You must be a superuser to use ALTER TEXT SEARCH TEMPLATE.

Parameters

name

The name (optionally schema-qualified) of an existing text search template.

new_name

The new name of the text search template.

new_schema

The new schema for the text search template.

Compatibility

There is no ALTER TEXT SEARCH TEMPLATE statement in the SQL standard.

See Also

CREATE TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

ALTER TRIGGER

Name

ALTER TRIGGER — change the definition of a trigger

Synopsis

```
ALTER TRIGGER name ON table_name RENAME TO new_name
```

Description

ALTER TRIGGER changes properties of an existing trigger. The RENAME clause changes the name of the given trigger without otherwise changing the trigger definition.

You must own the table on which the trigger acts to be allowed to change its properties.

Parameters

name

The name of an existing trigger to alter.

table_name

The name of the table on which this trigger acts.

new_name

The new name for the trigger.

Notes

The ability to temporarily enable or disable a trigger is provided by ALTER TABLE, not by ALTER TRIGGER, because ALTER TRIGGER has no convenient way to express the option of enabling or disabling all of a table's triggers at once.

Examples

To rename an existing trigger:

```
ALTER TRIGGER emp_stamp ON emp RENAME TO emp_track_chgs;
```

Compatibility

ALTER TRIGGER is a PostgreSQL extension of the SQL standard.

See Also

ALTER TABLE

ALTER TYPE

Name

ALTER TYPE — change the definition of a type

Synopsis

```
ALTER TYPE name action [, ... ]
ALTER TYPE name OWNER TO new_owner
ALTER TYPE name RENAME ATTRIBUTE attribute_name TO new_attribute_name [ CASCADE | RESTRICT ]
ALTER TYPE name RENAME TO new_name
ALTER TYPE name SET SCHEMA new_schema
ALTER TYPE name ADD VALUE [ IF NOT EXISTS ] new_enum_value [ { BEFORE | AFTER } existing_en

where action is one of:

    ADD ATTRIBUTE attribute_name data_type [ COLLATE collation ] [ CASCADE | RESTRICT ]
    DROP ATTRIBUTE [ IF EXISTS ] attribute_name [ CASCADE | RESTRICT ]
    ALTER ATTRIBUTE attribute_name [ SET DATA ] TYPE data_type [ COLLATE collation ] [ CASC
```

Description

ALTER TYPE changes the definition of an existing type. There are several subforms:

ADD ATTRIBUTE

This form adds a new attribute to a composite type, using the same syntax as CREATE TYPE.

DROP ATTRIBUTE [IF EXISTS]

This form drops an attribute from a composite type. If IF EXISTS is specified and the attribute does not exist, no error is thrown. In this case a notice is issued instead.

SET DATA TYPE

This form changes the type of an attribute of a composite type.

OWNER

This form changes the owner of the type.

RENAME

This form changes the name of the type or the name of an individual attribute of a composite type.

SET SCHEMA

This form moves the type into another schema.

ADD VALUE [IF NOT EXISTS] [BEFORE | AFTER]

This form adds a new value to an enum type. The new value's place in the enum's ordering can be specified as being BEFORE or AFTER one of the existing values. Otherwise, the new item is added at the end of the list of values.

If `IF NOT EXISTS` is specified, it is not an error if the type already contains the new value: a notice is issued but no other action is taken. Otherwise, an error will occur if the new value is already present.

`CASCADE`

Automatically propagate the operation to typed tables of the type being altered, and their descendants.

`RESTRICT`

Refuse the operation if the type being altered is the type of a typed table. This is the default.

The `ADD ATTRIBUTE`, `DROP ATTRIBUTE`, and `ALTER ATTRIBUTE` actions can be combined into a list of multiple alterations to apply in parallel. For example, it is possible to add several attributes and/or alter the type of several attributes in a single command.

You must own the type to use `ALTER TYPE`. To change the schema of a type, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the type's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the type. However, a superuser can alter ownership of any type anyway.) To add an attribute or alter an attribute type, you must also have `USAGE` privilege on the data type.

Parameters

name

The name (possibly schema-qualified) of an existing type to alter.

new_name

The new name for the type.

new_owner

The user name of the new owner of the type.

new_schema

The new schema for the type.

attribute_name

The name of the attribute to add, alter, or drop.

new_attribute_name

The new name of the attribute to be renamed.

data_type

The data type of the attribute to add, or the new type of the attribute to alter.

new_enum_value

The new value to be added to an enum type's list of values. Like all enum literals, it needs to be quoted.

existing_enum_value

The existing enum value that the new value should be added immediately before or after in the enum type's sort ordering. Like all enum literals, it needs to be quoted.

Notes

`ALTER TYPE ... ADD VALUE` (the form that adds a new value to an enum type) cannot be executed inside a transaction block.

Comparisons involving an added enum value will sometimes be slower than comparisons involving only original members of the enum type. This will usually only occur if `BEFORE` or `AFTER` is used to set the new value's sort position somewhere other than at the end of the list. However, sometimes it will happen even though the new value is added at the end (this occurs if the OID counter "wrapped around" since the original creation of the enum type). The slowdown is usually insignificant; but if it matters, optimal performance can be regained by dropping and recreating the enum type, or by dumping and reloading the database.

Examples

To rename a data type:

```
ALTER TYPE electronic_mail RENAME TO email;
```

To change the owner of the type `email` to `joe`:

```
ALTER TYPE email OWNER TO joe;
```

To change the schema of the type `email` to `customers`:

```
ALTER TYPE email SET SCHEMA customers;
```

To add a new attribute to a type:

```
ALTER TYPE compfoo ADD ATTRIBUTE f3 int;
```

To add a new value to an enum type in a particular sort position:

```
ALTER TYPE colors ADD VALUE 'orange' AFTER 'red';
```

Compatibility

The variants to add and drop attributes are part of the SQL standard; the other variants are PostgreSQL extensions.

See Also

CREATE TYPE, DROP TYPE

ALTER USER

Name

ALTER USER — change a database role

Synopsis

```
ALTER USER name [ [ WITH ] option [ ... ] ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEUSER | NOCREATEUSER
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | CONNECTION LIMIT connlimit
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
    | VALID UNTIL 'timestamp'

ALTER USER name RENAME TO new_name

ALTER USER name SET configuration_parameter { TO | = } { value | DEFAULT }
ALTER USER name SET configuration_parameter FROM CURRENT
ALTER USER name RESET configuration_parameter
ALTER USER name RESET ALL
```

Description

ALTER USER is now an alias for ALTER ROLE.

Compatibility

The ALTER USER statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

ALTER ROLE

ALTER USER MAPPING

Name

ALTER USER MAPPING — change the definition of a user mapping

Synopsis

```
ALTER USER MAPPING FOR { user_name | USER | CURRENT_USER | PUBLIC }
    SERVER server_name
    OPTIONS ( [ ADD | SET | DROP ] option ['value'] [, ... ] )
```

Description

ALTER USER MAPPING changes the definition of a user mapping.

The owner of a foreign server can alter user mappings for that server for any user. Also, a user can alter a user mapping for his own user name if USAGE privilege on the server has been granted to the user.

Parameters

user_name

User name of the mapping. CURRENT_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

server_name

Server name of the user mapping.

OPTIONS ([ADD | SET | DROP] *option* ['*value*'] [, ...])

Change options for the user mapping. The new options override any previously specified options. ADD, SET, and DROP specify the action to be performed. ADD is assumed if no operation is explicitly specified. Option names must be unique; options are also validated by the server's foreign-data wrapper.

Examples

Change the password for user mapping bob, server foo:

```
ALTER USER MAPPING FOR bob SERVER foo OPTIONS (user 'bob', password 'public');
```

Compatibility

ALTER USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). There is a subtle syntax issue: The standard omits the FOR key word. Since both CREATE USER MAPPING and DROP USER

`MAPPING` use `FOR` in analogous positions, and IBM DB2 (being the other major SQL/MED implementation) also requires it for `ALTER USER MAPPING`, PostgreSQL diverges from the standard here in the interest of consistency and interoperability.

See Also

CREATE USER MAPPING, DROP USER MAPPING

ALTER VIEW

Name

ALTER VIEW — change the definition of a view

Synopsis

```
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name SET DEFAULT expression
ALTER VIEW [ IF EXISTS ] name ALTER [ COLUMN ] column_name DROP DEFAULT
ALTER VIEW [ IF EXISTS ] name OWNER TO new_owner
ALTER VIEW [ IF EXISTS ] name RENAME TO new_name
ALTER VIEW [ IF EXISTS ] name SET SCHEMA new_schema
ALTER VIEW [ IF EXISTS ] name SET ( view_option_name [= view_option_value] [, ... ] )
ALTER VIEW [ IF EXISTS ] name RESET ( view_option_name [, ... ] )
```

Description

ALTER VIEW changes various auxiliary properties of a view. (If you want to modify the view's defining query, use CREATE OR REPLACE VIEW.)

You must own the view to use ALTER VIEW. To change a view's schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the view's schema. (These restrictions enforce that altering the owner doesn't do anything you couldn't do by dropping and recreating the view. However, a superuser can alter ownership of any view anyway.)

Parameters

name

The name (optionally schema-qualified) of an existing view.

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

SET/DROP DEFAULT

These forms set or remove the default value for a column. A view column's default value is substituted into any INSERT or UPDATE command whose target is the view, before applying any rules or triggers for the view. The view's default will therefore take precedence over any default values from underlying relations.

new_owner

The user name of the new owner of the view.

new_name

The new name for the view.

new_schema

The new schema for the view.

```
SET ( view_option_name [= view_option_value] [, ... ] )
RESET ( view_option_name [, ... ] )
```

Sets or resets a view option. Currently supported options are:

`check_option` (`string`)

Changes the check option of the view. The value must be `local` or `cascaded`.

`security_barrier` (`boolean`)

Changes the security-barrier property of the view. The value must be Boolean value, such as `true` or `false`.

Notes

For historical reasons, `ALTER TABLE` can be used with views too; but the only variants of `ALTER TABLE` that are allowed with views are equivalent to the ones shown above.

Examples

To rename the view `foo` to `bar`:

```
ALTER VIEW foo RENAME TO bar;
```

To attach a default column value to an updatable view:

```
CREATE TABLE base_table (id int, ts timestamptz);
CREATE VIEW a_view AS SELECT * FROM base_table;
ALTER VIEW a_view ALTER COLUMN ts SET DEFAULT now();
INSERT INTO base_table(id) VALUES(1);  -- ts will receive a NULL
INSERT INTO a_view(id) VALUES(2);  -- ts will receive the current time
```

Compatibility

`ALTER VIEW` is a PostgreSQL extension of the SQL standard.

See Also

CREATE VIEW, DROP VIEW

ANALYZE

Name

ANALYZE — collect statistics about a database

Synopsis

```
ANALYZE [ VERBOSE ] [ table_name [ ( column_name [, ...] ) ] ]
```

Description

ANALYZE collects statistics about the contents of tables in the database, and stores the results in the pg_statistic system catalog. Subsequently, the query planner uses these statistics to help determine the most efficient execution plans for queries.

With no parameter, ANALYZE examines every table in the current database. With a parameter, ANALYZE examines only that table. It is further possible to give a list of column names, in which case only the statistics for those columns are collected.

Parameters

VERBOSE

Enables display of progress messages.

table_name

The name (possibly schema-qualified) of a specific table to analyze. If omitted, all regular tables (but not foreign tables) in the current database are analyzed.

column_name

The name of a specific column to analyze. Defaults to all columns.

Outputs

When VERBOSE is specified, ANALYZE emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

Notes

Foreign tables are analyzed only when explicitly selected. Not all foreign data wrappers support ANALYZE. If the table's wrapper does not support ANALYZE, the command prints a warning and does nothing.

In the default PostgreSQL configuration, the autovacuum daemon (see Section 23.1.6) takes care of automatic analyzing of tables when they are first loaded with data, and as they change throughout regular operation. When autovacuum is disabled, it is a good idea to run ANALYZE periodically, or just after making major changes in the contents of a table. Accurate statistics will help the planner

to choose the most appropriate query plan, and thereby improve the speed of query processing. A common strategy for read-mostly databases is to run VACUUM and ANALYZE once a day during a low-usage time of day. (This will not be sufficient if there is heavy update activity.)

ANALYZE requires only a read lock on the target table, so it can run in parallel with other activity on the table.

The statistics collected by ANALYZE usually include a list of some of the most common values in each column and a histogram showing the approximate data distribution in each column. One or both of these can be omitted if ANALYZE deems them uninteresting (for example, in a unique-key column, there are no common values) or if the column data type does not support the appropriate operators. There is more information about the statistics in Chapter 23.

For large tables, ANALYZE takes a random sample of the table contents, rather than examining every row. This allows even very large tables to be analyzed in a small amount of time. Note, however, that the statistics are only approximate, and will change slightly each time ANALYZE is run, even if the actual table contents did not change. This might result in small changes in the planner's estimated costs shown by EXPLAIN. In rare situations, this non-determinism will cause the planner's choices of query plans to change after ANALYZE is run. To avoid this, raise the amount of statistics collected by ANALYZE, as described below.

The extent of analysis can be controlled by adjusting the default_statistics_target configuration variable, or on a column-by-column basis by setting the per-column statistics target with ALTER TABLE ... ALTER COLUMN ... SET STATISTICS (see ALTER TABLE). The target value sets the maximum number of entries in the most-common-value list and the maximum number of bins in the histogram. The default target value is 100, but this can be adjusted up or down to trade off accuracy of planner estimates against the time taken for ANALYZE and the amount of space occupied in pg_statistic. In particular, setting the statistics target to zero disables collection of statistics for that column. It might be useful to do that for columns that are never used as part of the WHERE, GROUP BY, or ORDER BY clauses of queries, since the planner will have no use for statistics on such columns.

The largest statistics target among the columns being analyzed determines the number of table rows sampled to prepare the statistics. Increasing the target causes a proportional increase in the time and space needed to do ANALYZE.

One of the values estimated by ANALYZE is the number of distinct values that appear in each column. Because only a subset of the rows are examined, this estimate can sometimes be quite inaccurate, even with the largest possible statistics target. If this inaccuracy leads to bad query plans, a more accurate value can be determined manually and then installed with ALTER TABLE ... ALTER COLUMN ... SET (n_distinct = ...) (see ALTER TABLE).

If the table being analyzed has one or more children, ANALYZE will gather statistics twice: once on the rows of the parent table only, and a second time on the rows of the parent table with all of its children. This second set of statistics is needed when planning queries that traverse the entire inheritance tree. The autovacuum daemon, however, will only consider inserts or updates on the parent table itself when deciding whether to trigger an automatic analyze for that table. If that table is rarely inserted into or updated, the inheritance statistics will not be up to date unless you run ANALYZE manually.

If the table being analyzed is completely empty, ANALYZE will not record new statistics for that table. Any existing statistics will be retained.

Compatibility

There is no ANALYZE statement in the SQL standard.

See Also

VACUUM, vacuumdb, Section 18.4.4, Section 23.1.6

BEGIN

Name

BEGIN — start a transaction block

Synopsis

```
BEGIN [ WORK | TRANSACTION ] [ transaction_mode [, ...] ]

where transaction_mode is one of:

    ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED
    READ WRITE | READ ONLY
    [ NOT ] DEFERRABLE
```

Description

BEGIN initiates a transaction block, that is, all statements after a BEGIN command will be executed in a single transaction until an explicit COMMIT or ROLLBACK is given. By default (without BEGIN), PostgreSQL executes transactions in "autocommit" mode, that is, each statement is executed in its own transaction and a commit is implicitly performed at the end of the statement (if execution was successful, otherwise a rollback is done).

Statements are executed more quickly in a transaction block, because transaction start/commit requires significant CPU and disk activity. Execution of multiple statements inside a transaction is also useful to ensure consistency when making several related changes: other sessions will be unable to see the intermediate states wherein not all the related updates have been done.

If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Refer to SET TRANSACTION for information on the meaning of the other parameters to this statement.

Notes

START TRANSACTION has the same functionality as BEGIN.

Use COMMIT or ROLLBACK to terminate a transaction block.

Issuing BEGIN when already inside a transaction block will provoke a warning message. The state of the transaction is not affected. To nest transactions within a transaction block, use savepoints (see SAVEPOINT).

For reasons of backwards compatibility, the commas between successive *transaction_modes* can be omitted.

Examples

To begin a transaction block:

```
BEGIN;
```

Compatibility

BEGIN is a PostgreSQL language extension. It is equivalent to the SQL-standard command START TRANSACTION, whose reference page contains additional compatibility information.

The DEFERRABLE *transaction_mode* is a PostgreSQL language extension.

Incidentally, the BEGIN key word is used for a different purpose in embedded SQL. You are advised to be careful about the transaction semantics when porting database applications.

See Also

COMMIT, ROLLBACK, START TRANSACTION, SAVEPOINT

CHECKPOINT

Name

CHECKPOINT — force a transaction log checkpoint

Synopsis

```
CHECKPOINT
```

Description

A checkpoint is a point in the transaction log sequence at which all data files have been updated to reflect the information in the log. All data files will be flushed to disk. Refer to Section 29.4 for more details about what happens during a checkpoint.

The CHECKPOINT command forces an immediate checkpoint when the command is issued, without waiting for a regular checkpoint scheduled by the system (controlled by the settings in Section 18.5.2). CHECKPOINT is not intended for use during normal operation.

If executed during recovery, the CHECKPOINT command will force a restartpoint (see Section 29.4) rather than writing a new checkpoint.

Only superusers can call CHECKPOINT.

Compatibility

The CHECKPOINT command is a PostgreSQL language extension.

CLOSE

Name

CLOSE — close a cursor

Synopsis

```
CLOSE { name | ALL }
```

Description

CLOSE frees the resources associated with an open cursor. After the cursor is closed, no subsequent operations are allowed on it. A cursor should be closed when it is no longer needed.

Every non-holdable open cursor is implicitly closed when a transaction is terminated by COMMIT or ROLLBACK. A holdable cursor is implicitly closed if the transaction that created it aborts via ROLLBACK. If the creating transaction successfully commits, the holdable cursor remains open until an explicit CLOSE is executed, or the client disconnects.

Parameters

name

The name of an open cursor to close.

ALL

Close all open cursors.

Notes

PostgreSQL does not have an explicit OPEN cursor statement; a cursor is considered open when it is declared. Use the DECLARE statement to declare a cursor.

You can see all available cursors by querying the pg_cursors system view.

If a cursor is closed after a savepoint which is later rolled back, the CLOSE is not rolled back; that is, the cursor remains closed.

Examples

Close the cursor liahona:

```
CLOSE liahona;
```

Compatibility

`CLOSE` is fully conforming with the SQL standard. `CLOSE ALL` is a PostgreSQL extension.

See Also

DECLARE, FETCH, MOVE

CLUSTER

Name

CLUSTER — cluster a table according to an index

Synopsis

```
CLUSTER [VERBOSE] table_name [ USING index_name ]
CLUSTER [VERBOSE]
```

Description

`CLUSTER` instructs PostgreSQL to cluster the table specified by *table_name* based on the index specified by *index_name*. The index must already have been defined on *table_name*.

When a table is clustered, it is physically reordered based on the index information. Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order. (If one wishes, one can periodically recluster by issuing the command again. Also, setting the table's `FILLFACTOR` storage parameter to less than 100% can aid in preserving cluster ordering during updates, since updated rows are kept on the same page if enough space is available there.)

When a table is clustered, PostgreSQL remembers which index it was clustered by. The form `CLUSTER` *table_name* reclusters the table using the same index as before. You can also use the `CLUSTER` or `SET WITHOUT CLUSTER` forms of ALTER TABLE to set the index to be used for future cluster operations, or to clear any previous setting.

`CLUSTER` without any parameter reclusters all the previously-clustered tables in the current database that the calling user owns, or all such tables if called by a superuser. This form of `CLUSTER` cannot be executed inside a transaction block.

When a table is being clustered, an `ACCESS EXCLUSIVE` lock is acquired on it. This prevents any other database operations (both reads and writes) from operating on the table until the `CLUSTER` is finished.

Parameters

table_name

The name (possibly schema-qualified) of a table.

index_name

The name of an index.

`VERBOSE`

Prints a progress report as each table is clustered.

Notes

In cases where you are accessing single rows randomly within a table, the actual order of the data in the table is unimportant. However, if you tend to access some data more than others, and there is an index that groups them together, you will benefit from using `CLUSTER`. If you are requesting a range of indexed values from a table, or a single indexed value that has multiple rows that match, `CLUSTER` will help because once the index identifies the table page for the first row that matches, all other rows that match are probably already on the same table page, and so you save disk accesses and speed up the query.

`CLUSTER` can re-sort the table using either an index scan on the specified index, or (if the index is a b-tree) a sequential scan followed by sorting. It will attempt to choose the method that will be faster, based on planner cost parameters and available statistical information.

When an index scan is used, a temporary copy of the table is created that contains the table data in the index order. Temporary copies of each index on the table are created as well. Therefore, you need free space on disk at least equal to the sum of the table size and the index sizes.

When a sequential scan and sort is used, a temporary sort file is also created, so that the peak temporary space requirement is as much as double the table size, plus the index sizes. This method is often faster than the index scan method, but if the disk space requirement is intolerable, you can disable this choice by temporarily setting enable_sort to `off`.

It is advisable to set maintenance_work_mem to a reasonably large value (but not more than the amount of RAM you can dedicate to the `CLUSTER` operation) before clustering.

Because the planner records statistics about the ordering of tables, it is advisable to run ANALYZE on the newly clustered table. Otherwise, the planner might make poor choices of query plans.

Because `CLUSTER` remembers which indexes are clustered, one can cluster the tables one wants clustered manually the first time, then set up a periodic maintenance script that executes `CLUSTER` without any parameters, so that the desired tables are periodically reclustered.

Examples

Cluster the table `employees` on the basis of its index `employees_ind`:

```
CLUSTER employees USING employees_ind;
```

Cluster the `employees` table using the same index that was used before:

```
CLUSTER employees;
```

Cluster all tables in the database that have previously been clustered:

```
CLUSTER;
```

Compatibility

There is no `CLUSTER` statement in the SQL standard.

The syntax

```
CLUSTER index_name ON table_name
```

is also supported for compatibility with pre-8.3 PostgreSQL versions.

See Also

clusterdb

COMMENT

Name

COMMENT — define or change the comment of an object

Synopsis

```
COMMENT ON
{
  AGGREGATE aggregate_name ( aggregate_signature ) |
  CAST (source_type AS target_type) |
  COLLATION object_name |
  COLUMN relation_name.column_name |
  CONSTRAINT constraint_name ON table_name |
  CONVERSION object_name |
  DATABASE object_name |
  DOMAIN object_name |
  EXTENSION object_name |
  EVENT TRIGGER object_name |
  FOREIGN DATA WRAPPER object_name |
  FOREIGN TABLE object_name |
  FUNCTION function_name ( [ [ argmode ] [ argname ] argtype [, ...] ] ) |
  INDEX object_name |
  LARGE OBJECT large_object_oid |
  MATERIALIZED VIEW object_name |
  OPERATOR operator_name (left_type, right_type) |
  OPERATOR CLASS object_name USING index_method |
  OPERATOR FAMILY object_name USING index_method |
  [ PROCEDURAL ] LANGUAGE object_name |
  ROLE object_name |
  RULE rule_name ON table_name |
  SCHEMA object_name |
  SEQUENCE object_name |
  SERVER object_name |
  TABLE object_name |
  TABLESPACE object_name |
  TEXT SEARCH CONFIGURATION object_name |
  TEXT SEARCH DICTIONARY object_name |
  TEXT SEARCH PARSER object_name |
  TEXT SEARCH TEMPLATE object_name |
  TRIGGER trigger_name ON table_name |
  TYPE object_name |
  VIEW object_name
} IS 'text'

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ] [ argname ] argtype [ , .
```

Description

COMMENT stores a comment about a database object.

Only one comment string is stored for each object, so to modify a comment, issue a new COMMENT command for the same object. To remove a comment, write NULL in place of the text string. Comments are automatically dropped when their object is dropped.

For most kinds of object, only the object's owner can set the comment. Roles don't have owners, so the rule for COMMENT ON ROLE is that you must be superuser to comment on a superuser role, or have the CREATEROLE privilege to comment on non-superuser roles. Of course, a superuser can comment on anything.

Comments can be viewed using psql's \d family of commands. Other user interfaces to retrieve comments can be built atop the same built-in functions that psql uses, namely obj_description, col_description, and shobj_description (see Table 9-60).

Parameters

object_name
relation_name.column_name
aggregate_name
constraint_name
function_name
operator_name
rule_name
trigger_name

The name of the object to be commented. Names of tables, aggregates, collations, conversions, domains, foreign tables, functions, indexes, operators, operator classes, operator families, sequences, text search objects, types, and views can be schema-qualified. When commenting on a column, *relation_name* must refer to a table, view, composite type, or foreign table.

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

argmode

The mode of a function or aggregate argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that COMMENT does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of a function or aggregate argument. Note that COMMENT does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function or aggregate argument.

large_object_oid

The OID of the large object.

left_type
right_type

The data type(s) of the operator's arguments (optionally schema-qualified). Write `NONE` for the missing argument of a prefix or postfix operator.

`PROCEDURAL`

This is a noise word.

text

The new comment, written as a string literal; or `NULL` to drop the comment.

Notes

There is presently no security mechanism for viewing comments: any user connected to a database can see all the comments for objects in that database. For shared objects such as databases, roles, and tablespaces, comments are stored globally so any user connected to any database in the cluster can see all the comments for shared objects. Therefore, don't put security-critical information in comments.

Examples

Attach a comment to the table `mytable`:

```
COMMENT ON TABLE mytable IS 'This is my table.';
```

Remove it again:

```
COMMENT ON TABLE mytable IS NULL;
```

Some more examples:

```
COMMENT ON AGGREGATE my_aggregate (double precision) IS 'Computes sample variance';
COMMENT ON CAST (text AS int4) IS 'Allow casts from text to int4';
COMMENT ON COLLATION "fr_CA" IS 'Canadian French';
COMMENT ON COLUMN my_table.my_column IS 'Employee ID number';
COMMENT ON CONVERSION my_conv IS 'Conversion to UTF8';
COMMENT ON CONSTRAINT bar_col_cons ON bar IS 'Constrains column col';
COMMENT ON DATABASE my_database IS 'Development Database';
COMMENT ON DOMAIN my_domain IS 'Email Address Domain';
COMMENT ON EXTENSION hstore IS 'implements the hstore data type';
COMMENT ON FOREIGN DATA WRAPPER mywrapper IS 'my foreign data wrapper';
COMMENT ON FOREIGN TABLE my_foreign_table IS 'Employee Information in other database';
COMMENT ON FUNCTION my_function (timestamp) IS 'Returns Roman Numeral';
COMMENT ON INDEX my_index IS 'Enforces uniqueness on employee ID';
COMMENT ON LANGUAGE plpython IS 'Python support for stored procedures';
COMMENT ON LARGE OBJECT 346344 IS 'Planning document';
COMMENT ON MATERIALIZED VIEW my_matview IS 'Summary of order history';
COMMENT ON OPERATOR ^ (text, text) IS 'Performs intersection of two texts';
COMMENT ON OPERATOR - (NONE, integer) IS 'Unary minus';
COMMENT ON OPERATOR CLASS int4ops USING btree IS '4 byte integer operators for btrees';
```

```
COMMENT ON OPERATOR FAMILY integer_ops USING btree IS 'all integer operators for btrees'
COMMENT ON ROLE my_role IS 'Administration group for finance tables';
COMMENT ON RULE my_rule ON my_table IS 'Logs updates of employee records';
COMMENT ON SCHEMA my_schema IS 'Departmental data';
COMMENT ON SEQUENCE my_sequence IS 'Used to generate primary keys';
COMMENT ON SERVER myserver IS 'my foreign server';
COMMENT ON TABLE my_schema.my_table IS 'Employee Information';
COMMENT ON TABLESPACE my_tablespace IS 'Tablespace for indexes';
COMMENT ON TEXT SEARCH CONFIGURATION my_config IS 'Special word filtering';
COMMENT ON TEXT SEARCH DICTIONARY swedish IS 'Snowball stemmer for Swedish language';
COMMENT ON TEXT SEARCH PARSER my_parser IS 'Splits text into words';
COMMENT ON TEXT SEARCH TEMPLATE snowball IS 'Snowball stemmer';
COMMENT ON TRIGGER my_trigger ON my_table IS 'Used for RI';
COMMENT ON TYPE complex IS 'Complex number data type';
COMMENT ON VIEW my_view IS 'View of departmental costs';
```

Compatibility

There is no `COMMENT` command in the SQL standard.

COMMIT

Name

COMMIT — commit the current transaction

Synopsis

```
COMMIT [ WORK | TRANSACTION ]
```

Description

COMMIT commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Notes

Use ROLLBACK to abort a transaction.

Issuing COMMIT when not inside a transaction does no harm, but it will provoke a warning message.

Examples

To commit the current transaction and make all changes permanent:

```
COMMIT;
```

Compatibility

The SQL standard only specifies the two forms COMMIT and COMMIT WORK. Otherwise, this command is fully conforming.

See Also

BEGIN, ROLLBACK

COMMIT PREPARED

Name

`COMMIT PREPARED` — commit a transaction that was earlier prepared for two-phase commit

Synopsis

```
COMMIT PREPARED transaction_id
```

Description

`COMMIT PREPARED` commits a transaction that is in prepared state.

Parameters

`transaction_id`

The transaction identifier of the transaction that is to be committed.

Notes

To commit a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is committed immediately.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

Examples

Commit the transaction identified by the transaction identifier `foobar`:

```
COMMIT PREPARED 'foobar';
```

Compatibility

`COMMIT PREPARED` is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

PREPARE TRANSACTION, ROLLBACK PREPARED

COPY

Name

COPY — copy data between a file and a table

Synopsis

```
COPY table_name [ ( column_name [, ...] ) ]
    FROM { 'filename' | PROGRAM 'command' | STDIN }
    [ [ WITH ] ( option [, ...] ) ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
    TO { 'filename' | PROGRAM 'command' | STDOUT }
    [ [ WITH ] ( option [, ...] ) ]

where option can be one of:

    FORMAT format_name
    OIDS [ boolean ]
    FREEZE [ boolean ]
    DELIMITER 'delimiter_character'
    NULL 'null_string'
    HEADER [ boolean ]
    QUOTE 'quote_character'
    ESCAPE 'escape_character'
    FORCE_QUOTE { ( column_name [, ...] ) | * }
    FORCE_NOT_NULL ( column_name [, ...] )
    FORCE_NULL ( column_name [, ...] )
    ENCODING 'encoding_name'
```

Description

COPY moves data between PostgreSQL tables and standard file-system files. COPY TO copies the contents of a table *to* a file, while COPY FROM copies data *from* a file to a table (appending the data to whatever is in the table already). COPY TO can also copy the results of a SELECT query.

If a list of columns is specified, COPY will only copy the data in the specified columns to or from the file. If there are any columns in the table that are not in the column list, COPY FROM will insert the default values for those columns.

COPY with a file name instructs the PostgreSQL server to directly read from or write to a file. The file must be accessible by the PostgreSQL user (the user ID the server runs as) and the name must be specified from the viewpoint of the server. When PROGRAM is specified, the server executes the given command and reads from the standard output of the program, or writes to the standard input of the program. The command must be specified from the viewpoint of the server, and be executable by the PostgreSQL user. When STDIN or STDOUT is specified, data is transmitted via the connection between the client and the server.

Parameters

table_name

The name (optionally schema-qualified) of an existing table.

column_name

An optional list of columns to be copied. If no column list is specified, all columns of the table will be copied.

query

A SELECT or VALUES command whose results are to be copied. Note that parentheses are required around the query.

filename

The path name of the input or output file. An input file name can be an absolute or relative path, but an output file name must be an absolute path. Windows users might need to use an `E''` string and double any backslashes used in the path name.

`PROGRAM`

A command to execute. In `COPY FROM`, the input is read from standard output of the command, and in `COPY TO`, the output is written to the standard input of the command.

Note that the command is invoked by the shell, so if you need to pass any arguments to shell command that come from an untrusted source, you must be careful to strip or escape any special characters that might have a special meaning for the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in it.

`STDIN`

Specifies that input comes from the client application.

`STDOUT`

Specifies that output goes to the client application.

boolean

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

`FORMAT`

Selects the data format to be read or written: `text`, `csv` (Comma Separated Values), or `binary`. The default is `text`.

`OIDS`

Specifies copying the OID for each row. (An error is raised if `OIDS` is specified for a table that does not have OIDs, or in the case of copying a *query*.)

`FREEZE`

Requests copying the data with rows already frozen, just as they would be after running the `VACUUM FREEZE` command. This is intended as a performance option for initial data loading. Rows will be frozen only if the table being loaded has been created or truncated in the current subtransaction, there are no cursors open and there are no older snapshots held by this transaction.

Note that all other sessions will immediately be able to see the data once it has been successfully loaded. This violates the normal rules of MVCC visibility and users specifying should be aware of the potential problems this might cause.

`DELIMITER`

Specifies the character that separates columns within each row (line) of the file. The default is a tab character in text format, a comma in `CSV` format. This must be a single one-byte character. This option is not allowed when using `binary` format.

`NULL`

Specifies the string that represents a null value. The default is `\N` (backslash-N) in text format, and an unquoted empty string in `CSV` format. You might prefer an empty string even in text format for cases where you don't want to distinguish nulls from empty strings. This option is not allowed when using `binary` format.

> **Note:** When using `COPY FROM`, any data item that matches this string will be stored as a null value, so you should make sure that you use the same string as you used with `COPY TO`.

`HEADER`

Specifies that the file contains a header line with the names of each column in the file. On output, the first line contains the column names from the table, and on input, the first line is ignored. This option is allowed only when using `CSV` format.

`QUOTE`

Specifies the quoting character to be used when a data value is quoted. The default is double-quote. This must be a single one-byte character. This option is allowed only when using `CSV` format.

`ESCAPE`

Specifies the character that should appear before a data character that matches the `QUOTE` value. The default is the same as the `QUOTE` value (so that the quoting character is doubled if it appears in the data). This must be a single one-byte character. This option is allowed only when using `CSV` format.

`FORCE_QUOTE`

Forces quoting to be used for all non-`NULL` values in each specified column. `NULL` output is never quoted. If $\star$ is specified, non-`NULL` values will be quoted in all columns. This option is allowed only in `COPY TO`, and only when using `CSV` format.

`FORCE_NOT_NULL`

Do not match the specified columns' values against the null string. In the default case where the null string is empty, this means that empty values will be read as zero-length strings rather than nulls, even when they are not quoted. This option is allowed only in `COPY FROM`, and only when using `CSV` format.

`FORCE_NULL`

Match the specified columns' values against the null string, even if it has been quoted, and if a match is found set the value to `NULL`. In the default case where the null string is empty, this converts a quoted empty string into NULL. This option is allowed only in `COPY FROM`, and only when using `CSV` format.

ENCODING

Specifies that the file is encoded in the *encoding_name*. If this option is omitted, the current client encoding is used. See the Notes below for more details.

Outputs

On successful completion, a COPY command returns a command tag of the form

```
COPY count
```

The *count* is the number of rows copied.

> **Note:** psql will print this command tag only if the command was not `COPY ... TO STDOUT`, or the equivalent psql meta-command `\copy ... to stdout`. This is to prevent confusing the command tag with the data that was just printed.

Notes

COPY can only be used with plain tables, not with views. However, you can write `COPY (SELECT * FROM viewname) TO ...`.

COPY only deals with the specific table named; it does not copy data to or from child tables. Thus for example `COPY table TO` shows the same data as `SELECT * FROM ONLY table`. But `COPY (SELECT * FROM table) TO ...` can be used to dump all of the data in an inheritance hierarchy.

You must have select privilege on the table whose values are read by `COPY TO`, and insert privilege on the table into which values are inserted by `COPY FROM`. It is sufficient to have column privileges on the column(s) listed in the command.

Files named in a COPY command are read or written directly by the server, not by the client application. Therefore, they must reside on or be accessible to the database server machine, not the client. They must be accessible to and readable or writable by the PostgreSQL user (the user ID the server runs as), not the client. Similarly, the command specified with PROGRAM is executed directly by the server, not by the client application, must be executable by the PostgreSQL user. COPY naming a file or command is only allowed to database superusers, since it allows reading or writing any file that the server has privileges to access.

Do not confuse COPY with the psql instruction `\copy`. `\copy` invokes `COPY FROM STDIN` or `COPY TO STDOUT`, and then fetches/stores the data in a file accessible to the psql client. Thus, file accessibility and access rights depend on the client rather than the server when `\copy` is used.

It is recommended that the file name used in COPY always be specified as an absolute path. This is enforced by the server in the case of `COPY TO`, but for `COPY FROM` you do have the option of reading from a file specified by a relative path. The path will be interpreted relative to the working directory of the server process (normally the cluster's data directory), not the client's working directory.

Executing a command with PROGRAM might be restricted by the operating system's access control mechanisms, such as SELinux.

`COPY FROM` will invoke any triggers and check constraints on the destination table. However, it will not invoke rules.

COPY input and output is affected by DateStyle. To ensure portability to other PostgreSQL installations that might use non-default DateStyle settings, DateStyle should be set to ISO before using COPY TO. It is also a good idea to avoid dumping data with IntervalStyle set to sql_standard, because negative interval values might be misinterpreted by a server that has a different setting for IntervalStyle.

Input data is interpreted according to ENCODING option or the current client encoding, and output data is encoded in ENCODING or the current client encoding, even if the data does not pass through the client but is read from or written to a file directly by the server.

COPY stops operation at the first error. This should not lead to problems in the event of a COPY TO, but the target table will already have received earlier rows in a COPY FROM. These rows will not be visible or accessible, but they still occupy disk space. This might amount to a considerable amount of wasted disk space if the failure happened well into a large copy operation. You might wish to invoke VACUUM to recover the wasted space.

FORCE_NULL and FORCE_NOT_NULL can be used simultaneously on the same column. This results in converting quoted null strings to null values and unquoted null strings to empty strings.

File Formats

Text Format

When the text format is used, the data read or written is a text file with one line per table row. Columns in a row are separated by the delimiter character. The column values themselves are strings generated by the output function, or acceptable to the input function, of each attribute's data type. The specified null string is used in place of columns that are null. COPY FROM will raise an error if any line of the input file contains more or fewer columns than are expected. If OIDS is specified, the OID is read or written as the first column, preceding the user data columns.

End of data can be represented by a single line containing just backslash-period (\.). An end-of-data marker is not necessary when reading from a file, since the end of file serves perfectly well; it is needed only when copying data to or from client applications using pre-3.0 client protocol.

Backslash characters (\) can be used in the COPY data to quote data characters that might otherwise be taken as row or column delimiters. In particular, the following characters *must* be preceded by a backslash if they appear as part of a column value: backslash itself, newline, carriage return, and the current delimiter character.

The specified null string is sent by COPY TO without adding any backslashes; conversely, COPY FROM matches the input against the null string before removing backslashes. Therefore, a null string such as \N cannot be confused with the actual data value \N (which would be represented as \\N).

The following special backslash sequences are recognized by COPY FROM:

Sequence	Represents
\b	Backspace (ASCII 8)
\f	Form feed (ASCII 12)
\n	Newline (ASCII 10)
\r	Carriage return (ASCII 13)
\t	Tab (ASCII 9)
\v	Vertical tab (ASCII 11)

Sequence	Represents
digits	Backslash followed by one to three octal digits specifies the character with that numeric code
\x*digits*	Backslash x followed by one or two hex digits specifies the character with that numeric code

Presently, COPY TO will never emit an octal or hex-digits backslash sequence, but it does use the other sequences listed above for those control characters.

Any other backslashed character that is not mentioned in the above table will be taken to represent itself. However, beware of adding backslashes unnecessarily, since that might accidentally produce a string matching the end-of-data marker (\.) or the null string (\N by default). These strings will be recognized before any other backslash processing is done.

It is strongly recommended that applications generating COPY data convert data newlines and carriage returns to the \n and \r sequences respectively. At present it is possible to represent a data carriage return by a backslash and carriage return, and to represent a data newline by a backslash and newline. However, these representations might not be accepted in future releases. They are also highly vulnerable to corruption if the COPY file is transferred across different machines (for example, from Unix to Windows or vice versa).

COPY TO will terminate each row with a Unix-style newline ("\n"). Servers running on Microsoft Windows instead output carriage return/newline ("\r\n"), but only for COPY to a server file; for consistency across platforms, COPY TO STDOUT always sends "\n" regardless of server platform. COPY FROM can handle lines ending with newlines, carriage returns, or carriage return/newlines. To reduce the risk of error due to un-backslashed newlines or carriage returns that were meant as data, COPY FROM will complain if the line endings in the input are not all alike.

CSV Format

This format option is used for importing and exporting the Comma Separated Value (CSV) file format used by many other programs, such as spreadsheets. Instead of the escaping rules used by PostgreSQL's standard text format, it produces and recognizes the common CSV escaping mechanism.

The values in each record are separated by the DELIMITER character. If the value contains the delimiter character, the QUOTE character, the NULL string, a carriage return, or line feed character, then the whole value is prefixed and suffixed by the QUOTE character, and any occurrence within the value of a QUOTE character or the ESCAPE character is preceded by the escape character. You can also use FORCE_QUOTE to force quotes when outputting non-NULL values in specific columns.

The CSV format has no standard way to distinguish a NULL value from an empty string. PostgreSQL's COPY handles this by quoting. A NULL is output as the NULL parameter string and is not quoted, while a non-NULL value matching the NULL parameter string is quoted. For example, with the default settings, a NULL is written as an unquoted empty string, while an empty string data value is written with double quotes (""). Reading values follows similar rules. You can use FORCE_NOT_NULL to prevent NULL input comparisons for specific columns. You can also use FORCE_NULL to convert quoted null string data values to NULL.

Because backslash is not a special character in the CSV format, \., the end-of-data marker, could also appear as a data value. To avoid any misinterpretation, a \. data value appearing as a lone entry on a line is automatically quoted on output, and on input, if quoted, is not interpreted as the end-of-data marker. If you are loading a file created by another application that has a single unquoted column and might have a value of \., you might need to quote that value in the input file.

Note: In `CSV` format, all characters are significant. A quoted value surrounded by white space, or any characters other than `DELIMITER`, will include those characters. This can cause errors if you import data from a system that pads `CSV` lines with white space out to some fixed width. If such a situation arises you might need to preprocess the `CSV` file to remove the trailing white space, before importing the data into PostgreSQL.

Note: CSV format will both recognize and produce CSV files with quoted values containing embedded carriage returns and line feeds. Thus the files are not strictly one line per table row like text-format files.

Note: Many programs produce strange and occasionally perverse CSV files, so the file format is more a convention than a standard. Thus you might encounter some files that cannot be imported using this mechanism, and `COPY` might produce files that other programs cannot process.

Binary Format

The `binary` format option causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the text and `CSV` formats, but a binary-format file is less portable across machine architectures and PostgreSQL versions. Also, the binary format is very data type specific; for example it will not work to output binary data from a `smallint` column and read it into an `integer` column, even though that would work fine in text format.

The `binary` file format consists of a file header, zero or more tuples containing the row data, and a file trailer. Headers and data are in network byte order.

Note: PostgreSQL releases before 7.4 used a different binary file format.

File Header

The file header consists of 15 bytes of fixed fields, followed by a variable-length header extension area. The fixed fields are:

Signature

11-byte sequence `PGCOPY\n\377\r\n\0` — note that the zero byte is a required part of the signature. (The signature is designed to allow easy identification of files that have been munged by a non-8-bit-clean transfer. This signature will be changed by end-of-line-translation filters, dropped zero bytes, dropped high bits, or parity changes.)

Flags field

32-bit integer bit mask to denote important aspects of the file format. Bits are numbered from 0 (LSB) to 31 (MSB). Note that this field is stored in network byte order (most significant byte first), as are all the integer fields used in the file format. Bits 16-31 are reserved to denote critical file format issues; a reader should abort if it finds an unexpected bit set in this range. Bits 0-15 are reserved to signal backwards-compatible format issues; a reader should simply ignore any

unexpected bits set in this range. Currently only one flag bit is defined, and the rest must be zero:

Bit 16

if 1, OIDs are included in the data; if 0, not

Header extension area length

32-bit integer, length in bytes of remainder of header, not including self. Currently, this is zero, and the first tuple follows immediately. Future changes to the format might allow additional data to be present in the header. A reader should silently skip over any header extension data it does not know what to do with.

The header extension area is envisioned to contain a sequence of self-identifying chunks. The flags field is not intended to tell readers what is in the extension area. Specific design of header extension contents is left for a later release.

This design allows for both backwards-compatible header additions (add header extension chunks, or set low-order flag bits) and non-backwards-compatible changes (set high-order flag bits to signal such changes, and add supporting data to the extension area if needed).

Tuples

Each tuple begins with a 16-bit integer count of the number of fields in the tuple. (Presently, all tuples in a table will have the same count, but that might not always be true.) Then, repeated for each field in the tuple, there is a 32-bit length word followed by that many bytes of field data. (The length word does not include itself, and can be zero.) As a special case, -1 indicates a NULL field value. No value bytes follow in the NULL case.

There is no alignment padding or any other extra data between fields.

Presently, all data values in a binary-format file are assumed to be in binary format (format code one). It is anticipated that a future extension might add a header field that allows per-column format codes to be specified.

To determine the appropriate binary format for the actual tuple data you should consult the PostgreSQL source, in particular the `*send` and `*recv` functions for each column's data type (typically these functions are found in the `src/backend/utils/adt/` directory of the source distribution).

If OIDs are included in the file, the OID field immediately follows the field-count word. It is a normal field except that it's not included in the field-count. In particular it has a length word — this will allow handling of 4-byte vs. 8-byte OIDs without too much pain, and will allow OIDs to be shown as null if that ever proves desirable.

File Trailer

The file trailer consists of a 16-bit integer word containing -1. This is easily distinguished from a tuple's field-count word.

A reader should report an error if a field-count word is neither -1 nor the expected number of columns. This provides an extra check against somehow getting out of sync with the data.

Examples

The following example copies a table to the client using the vertical bar (|) as the field delimiter:

```
COPY country TO STDOUT (DELIMITER '|');
```

To copy data from a file into the `country` table:

```
COPY country FROM '/usr1/proj/bray/sql/country_data';
```

To copy into a file just the countries whose names start with 'A':

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%') TO '/usr1/proj/bray/sql/a_list
```

To copy into a compressed file, you can pipe the output through an external compression program:

```
COPY country TO PROGRAM 'gzip > /usr1/proj/bray/sql/country_data.gz';
```

Here is a sample of data suitable for copying into a table from `STDIN`:

```
AF      AFGHANISTAN
AL      ALBANIA
DZ      ALGERIA
ZM      ZAMBIA
ZW      ZIMBABWE
```

Note that the white space on each line is actually a tab character.

The following is the same data, output in binary format. The data is shown after filtering through the Unix utility `od -c`. The table has three columns; the first has type `char(2)`, the second has type `text`, and the third has type `integer`. All the rows have a null value in the third column.

```
0000000   P   G   C   O   P   Y  \n 377  \r  \n  \0  \0  \0  \0  \0  \0
0000020  \0  \0  \0  \0 003  \0  \0  \0 002   A   F  \0  \0  \0 013   A
0000040   F   G   H   A   N   I   S   T   A   N 377 377 377 377  \0 003
0000060  \0  \0  \0 002   A   L  \0  \0  \0 007   A   L   B   A   N   I
0000100   A 377 377 377 377  \0 003  \0  \0  \0 002   D   Z  \0  \0  \0
0000120 007   A   L   G   E   R   I   A 377 377 377 377  \0 003  \0  \0
0000140  \0 002   Z   M  \0  \0  \0 006   Z   A   M   B   I   A 377 377
0000160 377 377  \0 003  \0  \0  \0 002   Z   W  \0  \0  \0  \b   Z   I
0000200   M   B   A   B   W   E 377 377 377 377 377 377
```

Compatibility

There is no `COPY` statement in the SQL standard.

The following syntax was used before PostgreSQL version 9.0 and is still supported:

```
COPY table_name [ ( column_name [, ...] ) ]
    FROM { 'filename' | STDIN }
```

```
    [ [ WITH ]
          [ BINARY ]
          [ OIDS ]
          [ DELIMITER [ AS ] 'delimiter' ]
          [ NULL [ AS ] 'null string' ]
          [ CSV [ HEADER ]
                [ QUOTE [ AS ] 'quote' ]
                [ ESCAPE [ AS ] 'escape' ]
                [ FORCE NOT NULL column_name [, ...] ] ] ]

COPY { table_name [ ( column_name [, ...] ) ] | ( query ) }
    TO { 'filename' | STDOUT }
    [ [ WITH ]
          [ BINARY ]
          [ OIDS ]
          [ DELIMITER [ AS ] 'delimiter' ]
          [ NULL [ AS ] 'null string' ]
          [ CSV [ HEADER ]
                [ QUOTE [ AS ] 'quote' ]
                [ ESCAPE [ AS ] 'escape' ]
                [ FORCE QUOTE { column_name [, ...] | * } ] ] ]
```

Note that in this syntax, `BINARY` and `CSV` are treated as independent keywords, not as arguments of a `FORMAT` option.

The following syntax was used before PostgreSQL version 7.3 and is still supported:

```
COPY [ BINARY ] table_name [ WITH OIDS ]
    FROM { 'filename' | STDIN }
    [ [USING] DELIMITERS 'delimiter' ]
    [ WITH NULL AS 'null string' ]

COPY [ BINARY ] table_name [ WITH OIDS ]
    TO { 'filename' | STDOUT }
    [ [USING] DELIMITERS 'delimiter' ]
    [ WITH NULL AS 'null string' ]
```

CREATE AGGREGATE

Name

CREATE AGGREGATE — define a new aggregate function

Synopsis

```
CREATE AGGREGATE name ( [ argmode ] [ argname ] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mffunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
)

CREATE AGGREGATE name ( [ [ argmode ] [ argname ] arg_data_type [ , ... ] ]
                        ORDER BY [ argmode ] [ argname ] arg_data_type [ , ... ] ) (
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , INITCOND = initial_condition ]
    [ , HYPOTHETICAL ]
)

or the old syntax

CREATE AGGREGATE name (
    BASETYPE = base_type,
    SFUNC = sfunc,
    STYPE = state_data_type
    [ , SSPACE = state_data_size ]
    [ , FINALFUNC = ffunc ]
    [ , FINALFUNC_EXTRA ]
    [ , INITCOND = initial_condition ]
    [ , MSFUNC = msfunc ]
    [ , MINVFUNC = minvfunc ]
    [ , MSTYPE = mstate_data_type ]
    [ , MSSPACE = mstate_data_size ]
    [ , MFINALFUNC = mffunc ]
    [ , MFINALFUNC_EXTRA ]
    [ , MINITCOND = minitial_condition ]
    [ , SORTOP = sort_operator ]
)
```

Description

`CREATE AGGREGATE` defines a new aggregate function. Some basic and commonly-used aggregate functions are included with the distribution; they are documented in Section 9.20. If one defines new types or needs an aggregate function not already provided, then `CREATE AGGREGATE` can be used to provide the desired features.

If a schema name is given (for example, `CREATE AGGREGATE myschema.myagg ...`) then the aggregate function is created in the specified schema. Otherwise it is created in the current schema.

An aggregate function is identified by its name and input data type(s). Two aggregates in the same schema can have the same name if they operate on different input types. The name and input data type(s) of an aggregate must also be distinct from the name and input data type(s) of every ordinary function in the same schema. This behavior is identical to overloading of ordinary function names (see CREATE FUNCTION).

A simple aggregate function is made from one or two ordinary functions: a state transition function *`sfunc`*, and an optional final calculation function *`ffunc`*. These are used as follows:

```
sfunc( internal-state, next-data-values ) ---> next-internal-state
ffunc( internal-state ) ---> aggregate-value
```

PostgreSQL creates a temporary variable of data type *`stype`* to hold the current internal state of the aggregate. At each input row, the aggregate argument value(s) are calculated and the state transition function is invoked with the current state value and the new argument value(s) to calculate a new internal state value. After all the rows have been processed, the final function is invoked once to calculate the aggregate's return value. If there is no final function then the ending state value is returned as-is.

An aggregate function can provide an initial condition, that is, an initial value for the internal state value. This is specified and stored in the database as a value of type `text`, but it must be a valid external representation of a constant of the state value data type. If it is not supplied then the state value starts out null.

If the state transition function is declared "strict", then it cannot be called with null inputs. With such a transition function, aggregate execution behaves as follows. Rows with any null input values are ignored (the function is not called and the previous state value is retained). If the initial state value is null, then at the first row with all-nonnull input values, the first argument value replaces the state value, and the transition function is invoked at each subsequent row with all-nonnull input values. This is handy for implementing aggregates like `max`. Note that this behavior is only available when *`state_data_type`* is the same as the first *`arg_data_type`*. When these types are different, you must supply a nonnull initial condition or use a nonstrict transition function.

If the state transition function is not strict, then it will be called unconditionally at each input row, and must deal with null inputs and null state values for itself. This allows the aggregate author to have full control over the aggregate's handling of null values.

If the final function is declared "strict", then it will not be called when the ending state value is null; instead a null result will be returned automatically. (Of course this is just the normal behavior of strict functions.) In any case the final function has the option of returning a null value. For example, the final function for `avg` returns null when it sees there were zero input rows.

Sometimes it is useful to declare the final function as taking not just the state value, but extra parameters corresponding to the aggregate's input values. The main reason for doing this is if the final function is polymorphic and the state value's data type would be inadequate to pin down the result type. These extra parameters are always passed as NULL (and so the final function must not be strict when the `FINALFUNC_EXTRA` option is used), but nonetheless they are valid parameters. The final

function could for example make use of `get_fn_expr_argtype` to identify the actual argument type in the current call.

An aggregate can optionally support *moving-aggregate mode*, as described in Section 35.10.1. This requires specifying the `MSFUNC`, `MINVFUNC`, and `MSTYPE` parameters, and optionally the `MSPACE`, `MFINALFUNC`, `MFINALFUNC_EXTRA`, and `MINITCOND` parameters. Except for `MINVFUNC`, these parameters work like the corresponding simple-aggregate parameters without `M`; they define a separate implementation of the aggregate that includes an inverse transition function.

The syntax with `ORDER BY` in the parameter list creates a special type of aggregate called an *ordered-set aggregate*; or if `HYPOTHETICAL` is specified, then a *hypothetical-set aggregate* is created. These aggregates operate over groups of sorted values in order-dependent ways, so that specification of an input sort order is an essential part of a call. Also, they can have *direct* arguments, which are arguments that are evaluated only once per aggregation rather than once per input row. Hypothetical-set aggregates are a subclass of ordered-set aggregates in which some of the direct arguments are required to match, in number and data types, the aggregated argument columns. This allows the values of those direct arguments to be added to the collection of aggregate-input rows as an additional "hypothetical" row.

Aggregates that behave like `MIN` or `MAX` can sometimes be optimized by looking into an index instead of scanning every input row. If this aggregate can be so optimized, indicate it by specifying a *sort operator*. The basic requirement is that the aggregate must yield the first element in the sort ordering induced by the operator; in other words:

```
SELECT agg(col) FROM tab;
```

must be equivalent to:

```
SELECT col FROM tab ORDER BY col USING sortop LIMIT 1;
```

Further assumptions are that the aggregate ignores null inputs, and that it delivers a null result if and only if there were no non-null inputs. Ordinarily, a data type's $<$ operator is the proper sort operator for `MIN`, and $>$ is the proper sort operator for `MAX`. Note that the optimization will never actually take effect unless the specified operator is the "less than" or "greater than" strategy member of a B-tree index operator class.

To be able to create an aggregate function, you must have `USAGE` privilege on the argument types, the state type(s), and the return type, as well as `EXECUTE` privilege on the transition and final functions.

Parameters

name

The name (optionally schema-qualified) of the aggregate function to create.

argmode

The mode of an argument: `IN` or `VARIADIC`. (Aggregate functions do not support `OUT` arguments.) If omitted, the default is `IN`. Only the last argument can be marked `VARIADIC`.

argname

The name of an argument. This is currently only useful for documentation purposes. If omitted, the argument has no name.

arg_data_type

An input data type on which this aggregate function operates. To create a zero-argument aggregate function, write * in place of the list of argument specifications. (An example of such an aggregate is count(*).)

base_type

In the old syntax for CREATE AGGREGATE, the input data type is specified by a basetype parameter rather than being written next to the aggregate name. Note that this syntax allows only one input parameter. To define a zero-argument aggregate function with this syntax, specify the basetype as "ANY" (not *). Ordered-set aggregates cannot be defined with the old syntax.

sfunc

The name of the state transition function to be called for each input row. For a normal *N*-argument aggregate function, the *sfunc* must take *N*+1 arguments, the first being of type *state_data_type* and the rest matching the declared input data type(s) of the aggregate. The function must return a value of type *state_data_type*. This function takes the current state value and the current input data value(s), and returns the next state value.

For ordered-set (including hypothetical-set) aggregates, the state transition function receives only the current state value and the aggregated arguments, not the direct arguments. Otherwise it is the same.

state_data_type

The data type for the aggregate's state value.

state_data_size

The approximate average size (in bytes) of the aggregate's state value. If this parameter is omitted or is zero, a default estimate is used based on the *state_data_type*. The planner uses this value to estimate the memory required for a grouped aggregate query. The planner will consider using hash aggregation for such a query only if the hash table is estimated to fit in work_mem; therefore, large values of this parameter discourage use of hash aggregation.

ffunc

The name of the final function called to compute the aggregate's result after all input rows have been traversed. For a normal aggregate, this function must take a single argument of type *state_data_type*. The return data type of the aggregate is defined as the return type of this function. If *ffunc* is not specified, then the ending state value is used as the aggregate's result, and the return type is *state_data_type*.

For ordered-set (including hypothetical-set) aggregates, the final function receives not only the final state value, but also the values of all the direct arguments.

If FINALFUNC_EXTRA is specified, then in addition to the final state value and any direct arguments, the final function receives extra NULL values corresponding to the aggregate's regular (aggregated) arguments. This is mainly useful to allow correct resolution of the aggregate result type when a polymorphic aggregate is being defined.

initial_condition

The initial setting for the state value. This must be a string constant in the form accepted for the data type *state_data_type*. If not specified, the state value starts out null.

msfunc

The name of the forward state transition function to be called for each input row in moving-aggregate mode. This is exactly like the regular transition function, except that its first argument and result are of type *mstate_data_type*, which might be different from *state_data_type*.

minvfunc

The name of the inverse state transition function to be used in moving-aggregate mode. This function has the same argument and result types as *msfunc*, but it is used to remove a value from the current aggregate state, rather than add a value to it. The inverse transition function must have the same strictness attribute as the forward state transition function.

mstate_data_type

The data type for the aggregate's state value, when using moving-aggregate mode.

mstate_data_size

The approximate average size (in bytes) of the aggregate's state value, when using moving-aggregate mode. This works the same as *state_data_size*.

mffunc

The name of the final function called to compute the aggregate's result after all input rows have been traversed, when using moving-aggregate mode. This works the same as *ffunc*, except that its first argument's type is *mstate_data_type* and extra dummy arguments are specified by writing MFINALFUNC_EXTRA. The aggregate result type determined by *mffunc* or *mstate_data_type* must match that determined by the aggregate's regular implementation.

minitial_condition

The initial setting for the state value, when using moving-aggregate mode. This works the same as *initial_condition*.

sort_operator

The associated sort operator for a MIN- or MAX-like aggregate. This is just an operator name (possibly schema-qualified). The operator is assumed to have the same input data types as the aggregate (which must be a single-argument normal aggregate).

HYPOTHETICAL

For ordered-set aggregates only, this flag specifies that the aggregate arguments are to be processed according to the requirements for hypothetical-set aggregates: that is, the last few direct arguments must match the data types of the aggregated (WITHIN GROUP) arguments. The HYPOTHETICAL flag has no effect on run-time behavior, only on parse-time resolution of the data types and collations of the aggregate's arguments.

The parameters of CREATE AGGREGATE can be written in any order, not just the order illustrated above.

Notes

In parameters that specify support function names, you can write a schema name if needed, for example SFUNC = public.sum. Do not write argument types there, however — the argument types of the support functions are determined from other parameters.

If an aggregate supports moving-aggregate mode, it will improve calculation efficiency when the aggregate is used as a window function for a window with moving frame start (that is, a frame start mode other than UNBOUNDED PRECEDING). Conceptually, the forward transition function adds input values to the aggregate's state when they enter the window frame from the bottom, and the inverse transition function removes them again when they leave the frame at the top. So, when values are removed, they are always removed in the same order they were added. Whenever the inverse transition function is invoked, it will thus receive the earliest added but not yet removed argument value(s). The inverse transition function can assume that at least one row will remain in the current state after it

removes the oldest row. (When this would not be the case, the window function mechanism simply starts a fresh aggregation, rather than using the inverse transition function.)

The forward transition function for moving-aggregate mode is not allowed to return NULL as the new state value. If the inverse transition function returns NULL, this is taken as an indication that the inverse function cannot reverse the state calculation for this particular input, and so the aggregate calculation will be redone from scratch for the current frame starting position. This convention allows moving-aggregate mode to be used in situations where there are some infrequent cases that are impractical to reverse out of the running state value.

If no moving-aggregate implementation is supplied, the aggregate can still be used with moving frames, but PostgreSQL will recompute the whole aggregation whenever the start of the frame moves. Note that whether or not the aggregate supports moving-aggregate mode, PostgreSQL can handle a moving frame end without recalculation; this is done by continuing to add new values to the aggregate's state. It is assumed that the final function does not damage the aggregate's state value, so that the aggregation can be continued even after an aggregate result value has been obtained for one set of frame boundaries.

The syntax for ordered-set aggregates allows `VARIADIC` to be specified for both the last direct parameter and the last aggregated (`WITHIN GROUP`) parameter. However, the current implementation restricts use of `VARIADIC` in two ways. First, ordered-set aggregates can only use `VARIADIC "any"`, not other variadic array types. Second, if the last direct parameter is `VARIADIC "any"`, then there can be only one aggregated parameter and it must also be `VARIADIC "any"`. (In the representation used in the system catalogs, these two parameters are merged into a single `VARIADIC "any"` item, since `pg_proc` cannot represent functions with more than one `VARIADIC` parameter.) If the aggregate is a hypothetical-set aggregate, the direct arguments that match the `VARIADIC "any"` parameter are the hypothetical ones; any preceding parameters represent additional direct arguments that are not constrained to match the aggregated arguments.

Currently, ordered-set aggregates do not need to support moving-aggregate mode, since they cannot be used as window functions.

Examples

See Section 35.10.

Compatibility

`CREATE AGGREGATE` is a PostgreSQL language extension. The SQL standard does not provide for user-defined aggregate functions.

See Also

ALTER AGGREGATE, DROP AGGREGATE

CREATE CAST

Name

CREATE CAST — define a new cast

Synopsis

```
CREATE CAST (source_type AS target_type)
    WITH FUNCTION function_name (argument_type [, ...])
    [ AS ASSIGNMENT | AS IMPLICIT ]

CREATE CAST (source_type AS target_type)
    WITHOUT FUNCTION
    [ AS ASSIGNMENT | AS IMPLICIT ]

CREATE CAST (source_type AS target_type)
    WITH INOUT
    [ AS ASSIGNMENT | AS IMPLICIT ]
```

Description

`CREATE CAST` defines a new cast. A cast specifies how to perform a conversion between two data types. For example,

```
SELECT CAST(42 AS float8);
```

converts the integer constant 42 to type `float8` by invoking a previously specified function, in this case `float8(int4)`. (If no suitable cast has been defined, the conversion fails.)

Two types can be *binary coercible*, which means that the conversion can be performed "for free" without invoking any function. This requires that corresponding values use the same internal representation. For instance, the types `text` and `varchar` are binary coercible both ways. Binary coercibility is not necessarily a symmetric relationship. For example, the cast from `xml` to `text` can be performed for free in the present implementation, but the reverse direction requires a function that performs at least a syntax check. (Two types that are binary coercible both ways are also referred to as binary compatible.)

You can define a cast as an *I/O conversion cast* by using the `WITH INOUT` syntax. An I/O conversion cast is performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type. In many common cases, this feature avoids the need to write a separate cast function for conversion. An I/O conversion cast acts the same as a regular function-based cast; only the implementation is different.

By default, a cast can be invoked only by an explicit cast request, that is an explicit `CAST(x AS typename)` or `x::typename` construct.

If the cast is marked `AS ASSIGNMENT` then it can be invoked implicitly when assigning a value to a column of the target data type. For example, supposing that `foo.f1` is a column of type `text`, then:

```
INSERT INTO foo (f1) VALUES (42);
```

will be allowed if the cast from type `integer` to type `text` is marked `AS ASSIGNMENT`, otherwise not. (We generally use the term *assignment cast* to describe this kind of cast.)

If the cast is marked `AS IMPLICIT` then it can be invoked implicitly in any context, whether assignment or internally in an expression. (We generally use the term *implicit cast* to describe this kind of cast.) For example, consider this query:

```
SELECT 2 + 4.0;
```

The parser initially marks the constants as being of type `integer` and `numeric` respectively. There is no `integer + numeric` operator in the system catalogs, but there is a `numeric + numeric` operator. The query will therefore succeed if a cast from `integer` to `numeric` is available and is marked `AS IMPLICIT` — which in fact it is. The parser will apply the implicit cast and resolve the query as if it had been written

```
SELECT CAST ( 2 AS numeric ) + 4.0;
```

Now, the catalogs also provide a cast from `numeric` to `integer`. If that cast were marked `AS IMPLICIT` — which it is not — then the parser would be faced with choosing between the above interpretation and the alternative of casting the `numeric` constant to `integer` and applying the `integer + integer` operator. Lacking any knowledge of which choice to prefer, it would give up and declare the query ambiguous. The fact that only one of the two casts is implicit is the way in which we teach the parser to prefer resolution of a mixed `numeric`-and-`integer` expression as `numeric`; there is no built-in knowledge about that.

It is wise to be conservative about marking casts as implicit. An overabundance of implicit casting paths can cause PostgreSQL to choose surprising interpretations of commands, or to be unable to resolve commands at all because there are multiple possible interpretations. A good rule of thumb is to make a cast implicitly invokable only for information-preserving transformations between types in the same general type category. For example, the cast from `int2` to `int4` can reasonably be implicit, but the cast from `float8` to `int4` should probably be assignment-only. Cross-type-category casts, such as `text` to `int4`, are best made explicit-only.

> **Note:** Sometimes it is necessary for usability or standards-compliance reasons to provide multiple implicit casts among a set of types, resulting in ambiguity that cannot be avoided as above. The parser has a fallback heuristic based on *type categories* and *preferred types* that can help to provide desired behavior in such cases. See CREATE TYPE for more information.

To be able to create a cast, you must own the source or the target data type and have `USAGE` privilege on the other type. To create a binary-coercible cast, you must be superuser. (This restriction is made because an erroneous binary-coercible cast conversion can easily crash the server.)

Parameters

`source_type`

The name of the source data type of the cast.

`target_type`

The name of the target data type of the cast.

function_name(*argument_type* [, ...])

The function used to perform the cast. The function name can be schema-qualified. If it is not, the function will be looked up in the schema search path. The function's result data type must match the target type of the cast. Its arguments are discussed below.

WITHOUT FUNCTION

Indicates that the source type is binary-coercible to the target type, so no function is required to perform the cast.

WITH INOUT

Indicates that the cast is an I/O conversion cast, performed by invoking the output function of the source data type, and passing the resulting string to the input function of the target data type.

AS ASSIGNMENT

Indicates that the cast can be invoked implicitly in assignment contexts.

AS IMPLICIT

Indicates that the cast can be invoked implicitly in any context.

Cast implementation functions can have one to three arguments. The first argument type must be identical to or binary-coercible from the cast's source type. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise. (Bizarrely, the SQL standard demands different behaviors for explicit and implicit casts in some cases. This argument is supplied for functions that must implement such casts. It is not recommended that you design your own data types so that this matters.)

The return type of a cast function must be identical to or binary-coercible to the cast's target type.

Ordinarily a cast must have different source and target data types. However, it is allowed to declare a cast with identical source and target types if it has a cast implementation function with more than one argument. This is used to represent type-specific length coercion functions in the system catalogs. The named function is used to coerce a value of the type to the type modifier value given by its second argument.

When a cast has different source and target types and a function that takes more than one argument, it supports converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two cast steps, one to convert between data types and a second to apply the modifier.

A cast to or from a domain type currently has no effect. Casting to or from a domain uses the casts associated with its underlying type.

Notes

Use DROP CAST to remove user-defined casts.

Remember that if you want to be able to convert types both ways you need to declare casts both ways explicitly.

It is normally not necessary to create casts between user-defined types and the standard string types (`text`, `varchar`, and `char(n)`, as well as user-defined types that are defined to be in the string category). PostgreSQL provides automatic I/O conversion casts for that. The automatic casts to string types are treated as assignment casts, while the automatic casts from string types are explicit-only. You can override this behavior by declaring your own cast to replace an automatic cast, but usually

the only reason to do so is if you want the conversion to be more easily invokable than the standard assignment-only or explicit-only setting. Another possible reason is that you want the conversion to behave differently from the type's I/O function; but that is sufficiently surprising that you should think twice about whether it's a good idea. (A small number of the built-in types do indeed have different behaviors for conversions, mostly because of requirements of the SQL standard.)

While not required, it is recommended that you continue to follow this old convention of naming cast implementation functions after the target data type. Many users are used to being able to cast data types using a function-style notation, that is *typename*(*x*). This notation is in fact nothing more nor less than a call of the cast implementation function; it is not specially treated as a cast. If your conversion functions are not named to support this convention then you will have surprised users. Since PostgreSQL allows overloading of the same function name with different argument types, there is no difficulty in having multiple conversion functions from different types that all use the target type's name.

> **Note:** Actually the preceding paragraph is an oversimplification: there are two cases in which a function-call construct will be treated as a cast request without having matched it to an actual function. If a function call *name*(*x*) does not exactly match any existing function, but *name* is the name of a data type and `pg_cast` provides a binary-coercible cast to this type from the type of *x*, then the call will be construed as a binary-coercible cast. This exception is made so that binary-coercible casts can be invoked using functional syntax, even though they lack any function. Likewise, if there is no `pg_cast` entry but the cast would be to or from a string type, the call will be construed as an I/O conversion cast. This exception allows I/O conversion casts to be invoked using functional syntax.

> **Note:** There is also an exception to the exception: I/O conversion casts from composite types to string types cannot be invoked using functional syntax, but must be written in explicit cast syntax (either `CAST` or `::` notation). This exception was added because after the introduction of automatically-provided I/O conversion casts, it was found too easy to accidentally invoke such a cast when a function or column reference was intended.

Examples

To create an assignment cast from type `bigint` to type `int4` using the function `int4(bigint)`:

```
CREATE CAST (bigint AS int4) WITH FUNCTION int4(bigint) AS ASSIGNMENT;
```

(This cast is already predefined in the system.)

Compatibility

The `CREATE CAST` command conforms to the SQL standard, except that SQL does not make provisions for binary-coercible types or extra arguments to implementation functions. `AS IMPLICIT` is a PostgreSQL extension, too.

See Also

CREATE FUNCTION, CREATE TYPE, DROP CAST

CREATE COLLATION

Name

CREATE COLLATION — define a new collation

Synopsis

```
CREATE COLLATION name (
    [ LOCALE = locale, ]
    [ LC_COLLATE = lc_collate, ]
    [ LC_CTYPE = lc_ctype ]
)
CREATE COLLATION name FROM existing_collation
```

Description

CREATE COLLATION defines a new collation using the specified operating system locale settings, or by copying an existing collation.

To be able to create a collation, you must have CREATE privilege on the destination schema.

Parameters

name

The name of the collation. The collation name can be schema-qualified. If it is not, the collation is defined in the current schema. The collation name must be unique within that schema. (The system catalogs can contain collations with the same name for other encodings, but these are ignored if the database encoding does not match.)

locale

This is a shortcut for setting LC_COLLATE and LC_CTYPE at once. If you specify this, you cannot specify either of those parameters.

lc_collate

Use the specified operating system locale for the LC_COLLATE locale category. The locale must be applicable to the current database encoding. (See CREATE DATABASE for the precise rules.)

lc_ctype

Use the specified operating system locale for the LC_CTYPE locale category. The locale must be applicable to the current database encoding. (See CREATE DATABASE for the precise rules.)

existing_collation

The name of an existing collation to copy. The new collation will have the same properties as the existing one, but it will be an independent object.

Notes

Use `DROP COLLATION` to remove user-defined collations.

See Section 22.2 for more information about collation support in PostgreSQL.

Examples

To create a collation from the operating system locale `fr_FR.utf8` (assuming the current database encoding is `UTF8`):

```
CREATE COLLATION french (LOCALE = 'fr_FR.utf8');
```

To create a collation from an existing collation:

```
CREATE COLLATION german FROM "de_DE";
```

This can be convenient to be able to use operating-system-independent collation names in applications.

Compatibility

There is a `CREATE COLLATION` statement in the SQL standard, but it is limited to copying an existing collation. The syntax to create a new collation is a PostgreSQL extension.

See Also

ALTER COLLATION, DROP COLLATION

CREATE CONVERSION

Name

CREATE CONVERSION — define a new encoding conversion

Synopsis

```
CREATE [ DEFAULT ] CONVERSION name
    FOR source_encoding TO dest_encoding FROM function_name
```

Description

CREATE CONVERSION defines a new conversion between character set encodings. Also, conversions that are marked DEFAULT can be used for automatic encoding conversion between client and server. For this purpose, two conversions, from encoding A to B *and* from encoding B to A, must be defined.

To be able to create a conversion, you must have EXECUTE privilege on the function and CREATE privilege on the destination schema.

Parameters

DEFAULT

The DEFAULT clause indicates that this conversion is the default for this particular source to destination encoding. There should be only one default encoding in a schema for the encoding pair.

name

The name of the conversion. The conversion name can be schema-qualified. If it is not, the conversion is defined in the current schema. The conversion name must be unique within a schema.

source_encoding

The source encoding name.

dest_encoding

The destination encoding name.

function_name

The function used to perform the conversion. The function name can be schema-qualified. If it is not, the function will be looked up in the path.

The function must have the following signature:

```
conv_proc(
    integer,  -- source encoding ID
    integer,  -- destination encoding ID
    cstring,  -- source string (null terminated C string)
    internal, -- destination (fill with a null terminated C string)
    integer   -- source string length
) RETURNS void;
```

Notes

Use `DROP CONVERSION` to remove user-defined conversions.

The privileges required to create a conversion might be changed in a future release.

Examples

To create a conversion from encoding `UTF8` to `LATIN1` using `myfunc`:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc;
```

Compatibility

`CREATE CONVERSION` is a PostgreSQL extension. There is no `CREATE CONVERSION` statement in the SQL standard, but a `CREATE TRANSLATION` statement that is very similar in purpose and syntax.

See Also

ALTER CONVERSION, CREATE FUNCTION, DROP CONVERSION

CREATE DATABASE

Name

CREATE DATABASE — create a new database

Synopsis

```
CREATE DATABASE name
    [ [ WITH ] [ OWNER [=] user_name ]
           [ TEMPLATE [=] template ]
           [ ENCODING [=] encoding ]
           [ LC_COLLATE [=] lc_collate ]
           [ LC_CTYPE [=] lc_ctype ]
           [ TABLESPACE [=] tablespace_name ]
           [ CONNECTION LIMIT [=] connlimit ] ]
```

Description

CREATE DATABASE creates a new PostgreSQL database.

To create a database, you must be a superuser or have the special CREATEDB privilege. See CREATE USER.

By default, the new database will be created by cloning the standard system database template1. A different template can be specified by writing TEMPLATE *name*. In particular, by writing TEMPLATE template0, you can create a virgin database containing only the standard objects predefined by your version of PostgreSQL. This is useful if you wish to avoid copying any installation-local objects that might have been added to template1.

Parameters

name

The name of a database to create.

user_name

The role name of the user who will own the new database, or DEFAULT to use the default (namely, the user executing the command). To create a database owned by another role, you must be a direct or indirect member of that role, or be a superuser.

template

The name of the template from which to create the new database, or DEFAULT to use the default template (template1).

encoding

Character set encoding to use in the new database. Specify a string constant (e.g., 'SQL_ASCII'), or an integer encoding number, or DEFAULT to use the default encoding (namely, the encoding of the template database). The character sets supported by the PostgreSQL server are described in Section 22.3.1. See below for additional restrictions.

lc_collate

Collation order (LC_COLLATE) to use in the new database. This affects the sort order applied to strings, e.g. in queries with ORDER BY, as well as the order used in indexes on text columns. The default is to use the collation order of the template database. See below for additional restrictions.

lc_ctype

Character classification (LC_CTYPE) to use in the new database. This affects the categorization of characters, e.g. lower, upper and digit. The default is to use the character classification of the template database. See below for additional restrictions.

tablespace_name

The name of the tablespace that will be associated with the new database, or DEFAULT to use the template database's tablespace. This tablespace will be the default tablespace used for objects created in this database. See CREATE TABLESPACE for more information.

connlimit

How many concurrent connections can be made to this database. -1 (the default) means no limit.

Optional parameters can be written in any order, not only the order illustrated above.

Notes

CREATE DATABASE cannot be executed inside a transaction block.

Errors along the line of "could not initialize database directory" are most likely related to insufficient permissions on the data directory, a full disk, or other file system problems.

Use DROP DATABASE to remove a database.

The program createdb is a wrapper program around this command, provided for convenience.

Database-level configuration parameters (set via ALTER DATABASE) are not copied from the template database.

Although it is possible to copy a database other than template1 by specifying its name as the template, this is not (yet) intended as a general-purpose "COPY DATABASE" facility. The principal limitation is that no other sessions can be connected to the template database while it is being copied. CREATE DATABASE will fail if any other connection exists when it starts; otherwise, new connections to the template database are locked out until CREATE DATABASE completes. See Section 21.3 for more information.

The character set encoding specified for the new database must be compatible with the chosen locale settings (LC_COLLATE and LC_CTYPE). If the locale is C (or equivalently POSIX), then all encodings are allowed, but for other locale settings there is only one encoding that will work properly. (On Windows, however, UTF-8 encoding can be used with any locale.) CREATE DATABASE will allow superusers to specify SQL_ASCII encoding regardless of the locale settings, but this choice is deprecated and may result in misbehavior of character-string functions if data that is not encoding-compatible with the locale is stored in the database.

The encoding and locale settings must match those of the template database, except when template0 is used as template. This is because other databases might contain data that does not match the specified encoding, or might contain indexes whose sort ordering is affected by LC_COLLATE and LC_CTYPE. Copying such data would result in a database that is corrupt according to the new settings. template0, however, is known to not contain any data or indexes that would be affected.

The `CONNECTION LIMIT` option is only enforced approximately; if two new sessions start at about the same time when just one connection "slot" remains for the database, it is possible that both will fail. Also, the limit is not enforced against superusers.

Examples

To create a new database:

```
CREATE DATABASE lusiadas;
```

To create a database `sales` owned by user `salesapp` with a default tablespace of `salesspace`:

```
CREATE DATABASE sales OWNER salesapp TABLESPACE salesspace;
```

To create a database `music` which supports the ISO-8859-1 character set:

```
CREATE DATABASE music ENCODING 'LATIN1' TEMPLATE template0;
```

In this example, the `TEMPLATE template0` clause would only be required if `template1`'s encoding is not ISO-8859-1. Note that changing encoding might require selecting new `LC_COLLATE` and `LC_CTYPE` settings as well.

Compatibility

There is no `CREATE DATABASE` statement in the SQL standard. Databases are equivalent to catalogs, whose creation is implementation-defined.

See Also

ALTER DATABASE, DROP DATABASE

CREATE DOMAIN

Name

CREATE DOMAIN — define a new domain

Synopsis

```
CREATE DOMAIN name [ AS ] data_type
    [ COLLATE collation ]
    [ DEFAULT expression ]
    [ constraint [ ... ] ]

where constraint is:

[ CONSTRAINT constraint_name ]
{ NOT NULL | NULL | CHECK (expression) }
```

Description

CREATE DOMAIN creates a new domain. A domain is essentially a data type with optional constraints (restrictions on the allowed set of values). The user who defines a domain becomes its owner.

If a schema name is given (for example, CREATE DOMAIN myschema.mydomain ...) then the domain is created in the specified schema. Otherwise it is created in the current schema. The domain name must be unique among the types and domains existing in its schema.

Domains are useful for abstracting common constraints on fields into a single location for maintenance. For example, several tables might contain email address columns, all requiring the same CHECK constraint to verify the address syntax. Define a domain rather than setting up each table's constraint individually.

To be able to create a domain, you must have USAGE privilege on the underlying type.

Parameters

name

The name (optionally schema-qualified) of a domain to be created.

data_type

The underlying data type of the domain. This can include array specifiers.

collation

An optional collation for the domain. If no collation is specified, the underlying data type's default collation is used. The underlying type must be collatable if COLLATE is specified.

DEFAULT *expression*

The DEFAULT clause specifies a default value for columns of the domain data type. The value is any variable-free expression (but subqueries are not allowed). The data type of the default

expression must match the data type of the domain. If no default value is specified, then the default value is the null value.

The default expression will be used in any insert operation that does not specify a value for the column. If a default value is defined for a particular column, it overrides any default associated with the domain. In turn, the domain default overrides any default value associated with the underlying data type.

`CONSTRAINT` *`constraint_name`*

An optional name for a constraint. If not specified, the system generates a name.

`NOT NULL`

Values of this domain are normally prevented from being null. However, it is still possible for a domain with this constraint to take a null value if it is assigned a matching domain type that has become null, e.g. via a LEFT OUTER JOIN, or `INSERT INTO tab (domcol) VALUES ((SELECT domcol FROM tab WHERE false))`.

`NULL`

Values of this domain are allowed to be null. This is the default.

This clause is only intended for compatibility with nonstandard SQL databases. Its use is discouraged in new applications.

`CHECK (`*`expression`*`)`

`CHECK` clauses specify integrity constraints or tests which values of the domain must satisfy. Each constraint must be an expression producing a Boolean result. It should use the key word `VALUE` to refer to the value being tested.

Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than `VALUE`.

Examples

This example creates the `us_postal_code` data type and then uses the type in a table definition. A regular expression test is used to verify that the value looks like a valid US postal code:

```
CREATE DOMAIN us_postal_code AS TEXT
CHECK(
   VALUE ~ '^\d{5}$'
OR VALUE ~ '^\d{5}-\d{4}$'
);

CREATE TABLE us_snail_addy (
  address_id SERIAL PRIMARY KEY,
  street1 TEXT NOT NULL,
  street2 TEXT,
  street3 TEXT,
  city TEXT NOT NULL,
  postal us_postal_code NOT NULL
);
```

Compatibility

The command `CREATE DOMAIN` conforms to the SQL standard.

See Also

ALTER DOMAIN, DROP DOMAIN

CREATE EVENT TRIGGER

Name

CREATE EVENT TRIGGER — define a new event trigger

Synopsis

```
CREATE EVENT TRIGGER name
  ON event
  [ WHEN filter_variable IN (filter_value [, ... ]) [ AND ... ] ]
  EXECUTE PROCEDURE function_name()
```

Description

CREATE EVENT TRIGGER creates a new event trigger. Whenever the designated event occurs and the WHEN condition associated with the trigger, if any, is satisfied, the trigger function will be executed. For a general introduction to event triggers, see Chapter 37. The user who creates an event trigger becomes its owner.

Parameters

name

The name to give the new trigger. This name must be unique within the database.

event

The name of the event that triggers a call to the given function. See Section 37.1 for more information on event names.

filter_variable

The name of a variable used to filter events. This makes it possible to restrict the firing of the trigger to a subset of the cases in which it is supported. Currently the only supported *filter_variable* is TAG.

filter_value

A list of values for the associated *filter_variable* for which the trigger should fire. For TAG, this means a list of command tags (e.g. 'DROP FUNCTION').

function_name

A user-supplied function that is declared as taking no argument and returning type event_trigger.

Notes

Only superusers can create event triggers.

Event triggers are disabled in single-user mode (see postgres). If an erroneous event trigger disables the database so much that you can't even drop the trigger, restart in single-user mode and you'll be able to do that.

Examples

Forbid the execution of any DDL command:

```
CREATE OR REPLACE FUNCTION abort_any_command()
  RETURNS event_trigger
 LANGUAGE plpgsql
  AS $$
BEGIN
  RAISE EXCEPTION 'command % is disabled', tg_tag;
END;
$$;

CREATE EVENT TRIGGER abort_ddl ON ddl_command_start
   EXECUTE PROCEDURE abort_any_command();
```

Compatibility

There is no `CREATE EVENT TRIGGER` statement in the SQL standard.

See Also

ALTER EVENT TRIGGER, DROP EVENT TRIGGER, CREATE FUNCTION

CREATE EXTENSION

Name

CREATE EXTENSION — install an extension

Synopsis

```
CREATE EXTENSION [ IF NOT EXISTS ] extension_name
    [ WITH ] [ SCHEMA schema_name ]
             [ VERSION version ]
             [ FROM old_version ]
```

Description

CREATE EXTENSION loads a new extension into the current database. There must not be an extension of the same name already loaded.

Loading an extension essentially amounts to running the extension's script file. The script will typically create new SQL objects such as functions, data types, operators and index support methods. CREATE EXTENSION additionally records the identities of all the created objects, so that they can be dropped again if DROP EXTENSION is issued.

Loading an extension requires the same privileges that would be required to create its component objects. For most extensions this means superuser or database owner privileges are needed. The user who runs CREATE EXTENSION becomes the owner of the extension for purposes of later privilege checks, as well as the owner of any objects created by the extension's script.

Parameters

IF NOT EXISTS

Do not throw an error if an extension with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing extension is anything like the one that would have been created from the currently-available script file.

extension_name

The name of the extension to be installed. PostgreSQL will create the extension using details from the file SHAREDIR/extension/*extension_name*.control.

schema_name

The name of the schema in which to install the extension's objects, given that the extension allows its contents to be relocated. The named schema must already exist. If not specified, and the extension's control file does not specify a schema either, the current default object creation schema is used.

Remember that the extension itself is not considered to be within any schema: extensions have unqualified names that must be unique database-wide. But objects belonging to the extension can be within schemas.

version

The version of the extension to install. This can be written as either an identifier or a string literal. The default version is whatever is specified in the extension's control file.

old_version

FROM *old_version* must be specified when, and only when, you are attempting to install an extension that replaces an "old style" module that is just a collection of objects not packaged into an extension. This option causes CREATE EXTENSION to run an alternative installation script that absorbs the existing objects into the extension, instead of creating new objects. Be careful that SCHEMA specifies the schema containing these pre-existing objects.

The value to use for *old_version* is determined by the extension's author, and might vary if there is more than one version of the old-style module that can be upgraded into an extension. For the standard additional modules supplied with pre-9.1 PostgreSQL, use unpackaged for *old_version* when updating a module to extension style.

Notes

Before you can use CREATE EXTENSION to load an extension into a database, the extension's supporting files must be installed. Information about installing the extensions supplied with PostgreSQL can be found in Additional Supplied Modules.

The extensions currently available for loading can be identified from the pg_available_extensions or pg_available_extension_versions system views.

For information about writing new extensions, see Section 35.15.

Examples

Install the hstore extension into the current database:

```
CREATE EXTENSION hstore;
```

Update a pre-9.1 installation of hstore into extension style:

```
CREATE EXTENSION hstore SCHEMA public FROM unpackaged;
```

Be careful to specify the schema in which you installed the existing hstore objects.

Compatibility

CREATE EXTENSION is a PostgreSQL extension.

See Also

ALTER EXTENSION, DROP EXTENSION

CREATE FOREIGN DATA WRAPPER

Name

CREATE FOREIGN DATA WRAPPER — define a new foreign-data wrapper

Synopsis

```
CREATE FOREIGN DATA WRAPPER name
    [ HANDLER handler_function | NO HANDLER ]
    [ VALIDATOR validator_function | NO VALIDATOR ]
    [ OPTIONS ( option 'value' [, ... ] ) ]
```

Description

CREATE FOREIGN DATA WRAPPER creates a new foreign-data wrapper. The user who defines a foreign-data wrapper becomes its owner.

The foreign-data wrapper name must be unique within the database.

Only superusers can create foreign-data wrappers.

Parameters

name

The name of the foreign-data wrapper to be created.

HANDLER *handler_function*

handler_function is the name of a previously registered function that will be called to retrieve the execution functions for foreign tables. The handler function must take no arguments, and its return type must be fdw_handler.

It is possible to create a foreign-data wrapper with no handler function, but foreign tables using such a wrapper can only be declared, not accessed.

VALIDATOR *validator_function*

validator_function is the name of a previously registered function that will be called to check the generic options given to the foreign-data wrapper, as well as options for foreign servers, user mappings and foreign tables using the foreign-data wrapper. If no validator function or NO VALIDATOR is specified, then options will not be checked at creation time. (Foreign-data wrappers will possibly ignore or reject invalid option specifications at run time, depending on the implementation.) The validator function must take two arguments: one of type text[], which will contain the array of options as stored in the system catalogs, and one of type oid, which will be the OID of the system catalog containing the options. The return type is ignored; the function should report invalid options using the ereport(ERROR) function.

OPTIONS (*option* 'value' [, ...])

This clause specifies options for the new foreign-data wrapper. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Option names must be unique.

Notes

PostgreSQL's foreign-data functionality is still under active development. Optimization of queries is primitive (and mostly left to the wrapper, too). Thus, there is considerable room for future performance improvements.

Examples

Create a useless foreign-data wrapper `dummy`:

```
CREATE FOREIGN DATA WRAPPER dummy;
```

Create a foreign-data wrapper `file` with handler function `file_fdw_handler`:

```
CREATE FOREIGN DATA WRAPPER file HANDLER file_fdw_handler;
```

Create a foreign-data wrapper `mywrapper` with some options:

```
CREATE FOREIGN DATA WRAPPER mywrapper
    OPTIONS (debug 'true');
```

Compatibility

`CREATE FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED), with the exception that the `HANDLER` and `VALIDATOR` clauses are extensions and the standard clauses `LIBRARY` and `LANGUAGE` are not implemented in PostgreSQL.

Note, however, that the SQL/MED functionality as a whole is not yet conforming.

See Also

ALTER FOREIGN DATA WRAPPER, DROP FOREIGN DATA WRAPPER, CREATE SERVER, CREATE USER MAPPING, CREATE FOREIGN TABLE

CREATE FOREIGN TABLE

Name

CREATE FOREIGN TABLE — define a new foreign table

Synopsis

```
CREATE FOREIGN TABLE [ IF NOT EXISTS ] table_name ( [
    column_name data_type [ OPTIONS ( option 'value' [, ... ] ) ] [ COLLATE collation ] [ co
    [, ... ]
] )
  SERVER server_name
[ OPTIONS ( option 'value' [, ... ] ) ]

where column_constraint is:

[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  DEFAULT default_expr }
```

Description

CREATE FOREIGN TABLE creates a new foreign table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, CREATE FOREIGN TABLE myschema.mytable ...) then the table is created in the specified schema. Otherwise it is created in the current schema. The name of the foreign table must be distinct from the name of any other foreign table, table, sequence, index, view, or materialized view in the same schema.

CREATE FOREIGN TABLE also automatically creates a data type that represents the composite type corresponding to one row of the foreign table. Therefore, foreign tables cannot have the same name as any existing data type in the same schema.

To be able to create a foreign table, you must have USAGE privilege on the foreign server, as well as USAGE privilege on all column types used in the table.

Parameters

IF NOT EXISTS

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

table_name

The name (optionally schema-qualified) of the table to be created.

column_name

The name of a column to be created in the new table.

data_type

The data type of the column. This can include array specifiers. For more information on the data types supported by PostgreSQL, refer to Chapter 8.

NOT NULL

The column is not allowed to contain null values.

NULL

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

DEFAULT *default_expr*

The DEFAULT clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (subqueries and cross-references to other columns in the current table are not allowed). The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

server_name

The name of an existing foreign server to use for the foreign table. For details on defining a server, see CREATE SERVER.

OPTIONS (*option* '*value*' [, ...])

Options to be associated with the new foreign table or one of its columns. The allowed option names and values are specific to each foreign data wrapper and are validated using the foreign-data wrapper's validator function. Duplicate option names are not allowed (although it's OK for a table option and a column option to have the same name).

Examples

Create foreign table films, which will be accessed through the server film_server:

```
CREATE FOREIGN TABLE films (
    code        char(5) NOT NULL,
    title       varchar(40) NOT NULL,
    did         integer NOT NULL,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute
)
SERVER film_server;
```

Compatibility

The `CREATE FOREIGN TABLE` command largely conforms to the SQL standard; however, much as with `CREATE TABLE`, `NULL` constraints and zero-column foreign tables are permitted. The ability to specify a default value is also a PostgreSQL extension.

See Also

ALTER FOREIGN TABLE, DROP FOREIGN TABLE, CREATE TABLE, CREATE SERVER

CREATE FUNCTION

Name

CREATE FUNCTION — define a new function

Synopsis

```
CREATE [ OR REPLACE ] FUNCTION
    name ( [ [ argmode ] [ argname ] argtype [ { DEFAULT | = } default_expr ] [, ...] ] )
    [ RETURNS rettype
      | RETURNS TABLE ( column_name column_type [, ...] ) ]
  { LANGUAGE lang_name
    | WINDOW
    | IMMUTABLE | STABLE | VOLATILE | [ NOT ] LEAKPROOF
    | CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
    | [ EXTERNAL ] SECURITY INVOKER | [ EXTERNAL ] SECURITY DEFINER
    | COST execution_cost
    | ROWS result_rows
    | SET configuration_parameter { TO value | = value | FROM CURRENT }
    | AS 'definition'
    | AS 'obj_file', 'link_symbol'
  } ...
    [ WITH ( attribute [, ...] ) ]
```

Description

CREATE FUNCTION defines a new function. CREATE OR REPLACE FUNCTION will either create a new function, or replace an existing definition. To be able to define a function, the user must have the USAGE privilege on the language.

If a schema name is included, then the function is created in the specified schema. Otherwise it is created in the current schema. The name of the new function must not match any existing function with the same input argument types in the same schema. However, functions of different argument types can share a name (this is called *overloading*).

To replace the current definition of an existing function, use CREATE OR REPLACE FUNCTION. It is not possible to change the name or argument types of a function this way (if you tried, you would actually be creating a new, distinct function). Also, CREATE OR REPLACE FUNCTION will not let you change the return type of an existing function. To do that, you must drop and recreate the function. (When using OUT parameters, that means you cannot change the types of any OUT parameters except by dropping the function.)

When CREATE OR REPLACE FUNCTION is used to replace an existing function, the ownership and permissions of the function do not change. All other function properties are assigned the values specified or implied in the command. You must own the function to replace it (this includes being a member of the owning role).

If you drop and then recreate a function, the new function is not the same entity as the old; you will have to drop existing rules, views, triggers, etc. that refer to the old function. Use CREATE OR REPLACE FUNCTION to change a function definition without breaking objects that refer to the function. Also, ALTER FUNCTION can be used to change most of the auxiliary properties of an existing function.

The user that creates the function becomes the owner of the function.

To be able to create a function, you must have USAGE privilege on the argument types and the return type.

Parameters

name

The name (optionally schema-qualified) of the function to create.

argmode

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Only OUT arguments can follow a VARIADIC one. Also, OUT and INOUT arguments cannot be used together with the RETURNS TABLE notation.

argname

The name of an argument. Some languages (including SQL and PL/pgSQL) let you use the name in the function body. For other languages the name of an input argument is just extra documentation, so far as the function itself is concerned; but you can use input argument names when calling a function to improve readability (see Section 4.3). In any case, the name of an output argument is significant, because it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types can be base, composite, or domain types, or can reference the type of a table column.

Depending on the implementation language it might also be allowed to specify "pseudotypes" such as cstring. Pseudotypes indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing *table_name*.*column_name*%TYPE. Using this feature can sometimes help make a function independent of changes to the definition of a table.

default_expr

An expression to be used as default value if the parameter is not specified. The expression has to be coercible to the argument type of the parameter. Only input (including INOUT) parameters can have a default value. All input parameters following a parameter with a default value must have default values as well.

rettype

The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or can reference the type of a table column. Depending on the implementation language it might also be allowed to specify "pseudotypes" such as cstring. If the function is not supposed to return a value, specify void as the return type.

When there are OUT or INOUT parameters, the RETURNS clause can be omitted. If present, it must agree with the result type implied by the output parameters: RECORD if there are multiple output parameters, or the same type as the single output parameter.

The SETOF modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing *table_name*.*column_name*%TYPE.

column_name

The name of an output column in the RETURNS TABLE syntax. This is effectively another way of declaring a named OUT parameter, except that RETURNS TABLE also implies RETURNS SETOF.

column_type

The data type of an output column in the RETURNS TABLE syntax.

lang_name

The name of the language that the function is implemented in. It can be sql, c, internal, or the name of a user-defined procedural language, e.g. plpgsql. Enclosing the name in single quotes is deprecated and requires matching case.

WINDOW

WINDOW indicates that the function is a *window function* rather than a plain function. This is currently only useful for functions written in C. The WINDOW attribute cannot be changed when replacing an existing function definition.

IMMUTABLE
STABLE
VOLATILE

These attributes inform the query optimizer about the behavior of the function. At most one choice can be specified. If none of these appear, VOLATILE is the default assumption.

IMMUTABLE indicates that the function cannot modify the database and always returns the same result when given the same argument values; that is, it does not do database lookups or otherwise use information not directly present in its argument list. If this option is given, any call of the function with all-constant arguments can be immediately replaced with the function value.

STABLE indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same argument values, but that its result could change across SQL statements. This is the appropriate selection for functions whose results depend on database lookups, parameter variables (such as the current time zone), etc. (It is inappropriate for AFTER triggers that wish to query rows modified by the current command.) Also note that the current_timestamp family of functions qualify as stable, since their values do not change within a transaction.

VOLATILE indicates that the function value can change even within a single table scan, so no optimizations can be made. Relatively few database functions are volatile in this sense; some examples are random(), currval(), timeofday(). But note that any function that has side-effects must be classified volatile, even if its result is quite predictable, to prevent calls from being optimized away; an example is setval().

For additional details see Section 35.6.

LEAKPROOF

LEAKPROOF indicates that the function has no side effects. It reveals no information about its arguments other than by its return value. For example, a function which throws an error message for some argument values but not others, or which includes the argument values in any error message, is not leakproof. The query planner may push leakproof functions (but not others) into views created with the security_barrier option. See CREATE VIEW and Section 38.5. This option can only be set by the superuser.

`CALLED ON NULL INPUT`
`RETURNS NULL ON NULL INPUT`
`STRICT`

`CALLED ON NULL INPUT` (the default) indicates that the function will be called normally when some of its arguments are null. It is then the function author's responsibility to check for null values if necessary and respond appropriately.

`RETURNS NULL ON NULL INPUT` or `STRICT` indicates that the function always returns null whenever any of its arguments are null. If this parameter is specified, the function is not executed when there are null arguments; instead a null result is assumed automatically.

`[EXTERNAL] SECURITY INVOKER`
`[EXTERNAL] SECURITY DEFINER`

`SECURITY INVOKER` indicates that the function is to be executed with the privileges of the user that calls it. That is the default. `SECURITY DEFINER` specifies that the function is to be executed with the privileges of the user that created it.

The key word `EXTERNAL` is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all functions not only external ones.

`execution_cost`

A positive number giving the estimated execution cost for the function, in units of cpu_operator_cost. If the function returns a set, this is the cost per returned row. If the cost is not specified, 1 unit is assumed for C-language and internal functions, and 100 units for functions in all other languages. Larger values cause the planner to try to avoid evaluating the function more often than necessary.

`result_rows`

A positive number giving the estimated number of rows that the planner should expect the function to return. This is only allowed when the function is declared to return a set. The default assumption is 1000 rows.

`configuration_parameter`
`value`

The `SET` clause causes the specified configuration parameter to be set to the specified value when the function is entered, and then restored to its prior value when the function exits. `SET FROM CURRENT` saves the session's current value of the parameter as the value to be applied when the function is entered.

If a `SET` clause is attached to a function, then the effects of a `SET LOCAL` command executed inside the function for the same variable are restricted to the function: the configuration parameter's prior value is still restored at function exit. However, an ordinary `SET` command (without `LOCAL`) overrides the `SET` clause, much as it would do for a previous `SET LOCAL` command: the effects of such a command will persist after function exit, unless the current transaction is rolled back.

See SET and Chapter 18 for more information about allowed parameter names and values.

`definition`

A string constant defining the function; the meaning depends on the language. It can be an internal function name, the path to an object file, an SQL command, or text in a procedural language.

It is often helpful to use dollar quoting (see Section 4.1.2.4) to write the function definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function definition must be escaped by doubling them.

obj_file, *link_symbol*

This form of the AS clause is used for dynamically loadable C language functions when the function name in the C language source code is not the same as the name of the SQL function. The string *obj_file* is the name of the file containing the dynamically loadable object, and *link_symbol* is the function's link symbol, that is, the name of the function in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL function being defined.

When repeated CREATE FUNCTION calls refer to the same object file, the file is only loaded once per session. To unload and reload the file (perhaps during development), start a new session.

attribute

The historical way to specify optional pieces of information about the function. The following attributes can appear here:

isStrict

Equivalent to STRICT or RETURNS NULL ON NULL INPUT.

isCachable

isCachable is an obsolete equivalent of IMMUTABLE; it's still accepted for backwards-compatibility reasons.

Attribute names are not case-sensitive.

Refer to Section 35.3 for further information on writing functions.

Overloading

PostgreSQL allows function *overloading*; that is, the same name can be used for several different functions so long as they have distinct input argument types. However, the C names of all functions must be different, so you must give overloaded C functions different C names (for example, use the argument types as part of the C names).

Two functions are considered the same if they have the same names and *input* argument types, ignoring any OUT parameters. Thus for example these declarations conflict:

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, out text) ...
```

Functions that have different argument type lists will not be considered to conflict at creation time, but if defaults are provided they might conflict in use. For example, consider

```
CREATE FUNCTION foo(int) ...
CREATE FUNCTION foo(int, int default 42) ...
```

A call foo(10) will fail due to the ambiguity about which function should be called.

Notes

The full SQL type syntax is allowed for declaring a function's arguments and return value. However, parenthesized type modifiers (e.g., the precision field for type `numeric`) are discarded by `CREATE FUNCTION`. Thus for example `CREATE FUNCTION foo (varchar(10)) ...` is exactly the same as `CREATE FUNCTION foo (varchar) ...`.

When replacing an existing function with `CREATE OR REPLACE FUNCTION`, there are restrictions on changing parameter names. You cannot change the name already assigned to any input parameter (although you can add names to parameters that had none before). If there is more than one output parameter, you cannot change the names of the output parameters, because that would change the column names of the anonymous composite type that describes the function's result. These restrictions are made to ensure that existing calls of the function do not stop working when it is replaced.

If a function is declared `STRICT` with a `VARIADIC` argument, the strictness check tests that the variadic array *as a whole* is non-null. The function will still be called if the array has null elements.

Examples

Here are some trivial examples to help you get started. For more information and examples, see Section 35.3.

```
CREATE FUNCTION add(integer, integer) RETURNS integer
    AS 'select $1 + $2;'
    LANGUAGE SQL
    IMMUTABLE
    RETURNS NULL ON NULL INPUT;
```

Increment an integer, making use of an argument name, in PL/pgSQL:

```
CREATE OR REPLACE FUNCTION increment(i integer) RETURNS integer AS $$
        BEGIN
                RETURN i + 1;
        END;
$$ LANGUAGE plpgsql;
```

Return a record containing multiple output parameters:

```
CREATE FUNCTION dup(in int, out f1 int, out f2 text)
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

You can do the same thing more verbosely with an explicitly named composite type:

```
CREATE TYPE dup_result AS (f1 int, f2 text);

CREATE FUNCTION dup(int) RETURNS dup_result
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

Another way to return multiple columns is to use a TABLE function:

```
CREATE FUNCTION dup(int) RETURNS TABLE(f1 int, f2 text)
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;

SELECT * FROM dup(42);
```

However, a TABLE function is different from the preceding examples, because it actually returns a *set* of records, not just one record.

Writing SECURITY DEFINER Functions Safely

Because a SECURITY DEFINER function is executed with the privileges of the user that created it, care is needed to ensure that the function cannot be misused. For security, search_path should be set to exclude any schemas writable by untrusted users. This prevents malicious users from creating objects that mask objects used by the function. Particularly important in this regard is the temporary-table schema, which is searched first by default, and is normally writable by anyone. A secure arrangement can be had by forcing the temporary schema to be searched last. To do this, write pg_temp as the last entry in search_path. This function illustrates safe usage:

```
CREATE FUNCTION check_password(uname TEXT, pass TEXT)
RETURNS BOOLEAN AS $$
DECLARE passed BOOLEAN;
BEGIN
        SELECT  (pwd = $2) INTO passed
        FROM    pwds
        WHERE   username = $1;

        RETURN passed;
END;
$$  LANGUAGE plpgsql
    SECURITY DEFINER
    -- Set a secure search_path: trusted schema(s), then 'pg_temp'.
    SET search_path = admin, pg_temp;
```

Before PostgreSQL version 8.3, the SET option was not available, and so older functions may contain rather complicated logic to save, set, and restore search_path. The SET option is far easier to use for this purpose.

Another point to keep in mind is that by default, execute privilege is granted to PUBLIC for newly created functions (see GRANT for more information). Frequently you will wish to restrict use of a security definer function to only some users. To do that, you must revoke the default PUBLIC privileges and then grant execute privilege selectively. To avoid having a window where the new function is accessible to all, create it and set the privileges within a single transaction. For example:

```
BEGIN;
CREATE FUNCTION check_password(uname TEXT, pass TEXT) ... SECURITY DEFINER;
REVOKE ALL ON FUNCTION check_password(uname TEXT, pass TEXT) FROM PUBLIC;
GRANT EXECUTE ON FUNCTION check_password(uname TEXT, pass TEXT) TO admins;
COMMIT;
```

Compatibility

A `CREATE FUNCTION` command is defined in SQL:1999 and later. The PostgreSQL version is similar but not fully compatible. The attributes are not portable, neither are the different available languages.

For compatibility with some other database systems, *`argmode`* can be written either before or after *`argname`*. But only the first way is standard-compliant.

For parameter defaults, the SQL standard specifies only the syntax with the `DEFAULT` key word. The syntax with = is used in T-SQL and Firebird.

See Also

ALTER FUNCTION, DROP FUNCTION, GRANT, LOAD, REVOKE, createlang

CREATE GROUP

Name

CREATE GROUP — define a new database role

Synopsis

```
CREATE GROUP name [ [ WITH ] option [ ... ] ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEUSER | NOCREATEUSER
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
    | VALID UNTIL 'timestamp'
    | IN ROLE role_name [, ...]
    | IN GROUP role_name [, ...]
    | ROLE role_name [, ...]
    | ADMIN role_name [, ...]
    | USER role_name [, ...]
    | SYSID uid
```

Description

CREATE GROUP is now an alias for CREATE ROLE.

Compatibility

There is no CREATE GROUP statement in the SQL standard.

See Also

CREATE ROLE

CREATE INDEX

Name

CREATE INDEX — define a new index

Synopsis

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ name ] ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ] [ ASC | DESC ] [ NU
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

Description

CREATE INDEX constructs an index on the specified column(s) of the specified relation, which can be a table or a materialized view. Indexes are primarily used to enhance database performance (though inappropriate use can result in slower performance).

The key field(s) for the index are specified as column names, or alternatively as expressions written in parentheses. Multiple fields can be specified if the index method supports multicolumn indexes.

An index field can be an expression computed from the values of one or more columns of the table row. This feature can be used to obtain fast access to data based on some transformation of the basic data. For example, an index computed on upper(col) would allow the clause WHERE upper(col) = 'JIM' to use an index.

PostgreSQL provides the index methods B-tree, hash, GiST, SP-GiST, and GIN. Users can also define their own index methods, but that is fairly complicated.

When the WHERE clause is present, a *partial index* is created. A partial index is an index that contains entries for only a portion of a table, usually a portion that is more useful for indexing than the rest of the table. For example, if you have a table that contains both billed and unbilled orders where the unbilled orders take up a small fraction of the total table and yet that is an often used section, you can improve performance by creating an index on just that portion. Another possible application is to use WHERE with UNIQUE to enforce uniqueness over a subset of a table. See Section 11.8 for more discussion.

The expression used in the WHERE clause can refer only to columns of the underlying table, but it can use all columns, not just the ones being indexed. Presently, subqueries and aggregate expressions are also forbidden in WHERE. The same restrictions apply to index fields that are expressions.

All functions and operators used in an index definition must be "immutable", that is, their results must depend only on their arguments and never on any outside influence (such as the contents of another table or the current time). This restriction ensures that the behavior of the index is well-defined. To use a user-defined function in an index expression or WHERE clause, remember to mark the function immutable when you create it.

Parameters

`UNIQUE`

Causes the system to check for duplicate values in the table when the index is created (if data already exist) and each time data is added. Attempts to insert or update data which would result in duplicate entries will generate an error.

`CONCURRENTLY`

When this option is used, PostgreSQL will build the index without taking any locks that prevent concurrent inserts, updates, or deletes on the table; whereas a standard index build locks out writes (but not reads) on the table until it's done. There are several caveats to be aware of when using this option — see *Building Indexes Concurrently*.

`name`

The name of the index to be created. No schema name can be included here; the index is always created in the same schema as its parent table. If the name is omitted, PostgreSQL chooses a suitable name based on the parent table's name and the indexed column name(s).

`table_name`

The name (possibly schema-qualified) of the table to be indexed.

`method`

The name of the index method to be used. Choices are `btree`, `hash`, `gist`, `spgist` and `gin`. The default method is `btree`.

`column_name`

The name of a column of the table.

`expression`

An expression based on one or more columns of the table. The expression usually must be written with surrounding parentheses, as shown in the syntax. However, the parentheses can be omitted if the expression has the form of a function call.

`collation`

The name of the collation to use for the index. By default, the index uses the collation declared for the column to be indexed or the result collation of the expression to be indexed. Indexes with non-default collations can be useful for queries that involve expressions using non-default collations.

`opclass`

The name of an operator class. See below for details.

`ASC`

Specifies ascending sort order (which is the default).

`DESC`

Specifies descending sort order.

`NULLS FIRST`

Specifies that nulls sort before non-nulls. This is the default when `DESC` is specified.

`NULLS LAST`

Specifies that nulls sort after non-nulls. This is the default when `DESC` is not specified.

storage_parameter

The name of an index-method-specific storage parameter. See *Index Storage Parameters* for details.

tablespace_name

The tablespace in which to create the index. If not specified, default_tablespace is consulted, or temp_tablespaces for indexes on temporary tables.

predicate

The constraint expression for a partial index.

Index Storage Parameters

The optional WITH clause specifies *storage parameters* for the index. Each index method has its own set of allowed storage parameters. The B-tree, hash, GiST and SP-GiST index methods all accept this parameter:

FILLFACTOR

The fillfactor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (adding new largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any integer value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.

GiST indexes additionally accept this parameter:

BUFFERING

Determines whether the buffering build technique described in Section 56.4.1 is used to build the index. With OFF it is disabled, with ON it is enabled, and with AUTO it is initially disabled, but turned on on-the-fly once the index size reaches effective_cache_size. The default is AUTO.

GIN indexes accept a different parameter:

FASTUPDATE

This setting controls usage of the fast update technique described in Section 58.4.1. It is a Boolean parameter: ON enables fast update, OFF disables it. (Alternative spellings of ON and OFF are allowed as described in Section 18.1.) The default is ON.

> **Note:** Turning FASTUPDATE off via ALTER INDEX prevents future insertions from going into the list of pending index entries, but does not in itself flush previous entries. You might want to VACUUM the table afterward to ensure the pending list is emptied.

Building Indexes Concurrently

Creating an index can interfere with regular operation of a database. Normally PostgreSQL locks the table to be indexed against writes and performs the entire index build with a single scan of the table. Other transactions can still read the table, but if they try to insert, update, or delete rows in the table they will block until the index build is finished. This could have a severe effect if the system is a live production database. Very large tables can take many hours to be indexed, and even for smaller tables, an index build can lock out writers for periods that are unacceptably long for a production system.

PostgreSQL supports building indexes without locking out writes. This method is invoked by specifying the `CONCURRENTLY` option of `CREATE INDEX`. When this option is used, PostgreSQL must perform two scans of the table, and in addition it must wait for all existing transactions that could potentially use the index to terminate. Thus this method requires more total work than a standard index build and takes significantly longer to complete. However, since it allows normal operations to continue while the index is built, this method is useful for adding new indexes in a production environment. Of course, the extra CPU and I/O load imposed by the index creation might slow other operations.

In a concurrent index build, the index is actually entered into the system catalogs in one transaction, then two table scans occur in two more transactions. Any transaction active when the second table scan starts can block concurrent index creation until it completes, even transactions that only reference the table after the second table scan starts. Concurrent index creation serially waits for each old transaction to complete using the method outlined in section Section 48.60.

If a problem arises while scanning the table, such as a deadlock or a uniqueness violation in a unique index, the `CREATE INDEX` command will fail but leave behind an "invalid" index. This index will be ignored for querying purposes because it might be incomplete; however it will still consume update overhead. The psql `\d` command will report such an index as `INVALID`:

```
postgres=# \d tab
       Table "public.tab"
 Column |  Type   | Modifiers
--------+---------+-----------
 col    | integer |
Indexes:
    "idx" btree (col) INVALID
```

The recommended recovery method in such cases is to drop the index and try again to perform `CREATE INDEX CONCURRENTLY`. (Another possibility is to rebuild the index with `REINDEX`. However, since `REINDEX` does not support concurrent builds, this option is unlikely to seem attractive.)

Another caveat when building a unique index concurrently is that the uniqueness constraint is already being enforced against other transactions when the second table scan begins. This means that constraint violations could be reported in other queries prior to the index becoming available for use, or even in cases where the index build eventually fails. Also, if a failure does occur in the second scan, the "invalid" index continues to enforce its uniqueness constraint afterwards.

Concurrent builds of expression indexes and partial indexes are supported. Errors occurring in the evaluation of these expressions could cause behavior similar to that described above for unique constraint violations.

Regular index builds permit other regular index builds on the same table to occur in parallel, but only one concurrent index build can occur on a table at a time. In both cases, no other types of schema modification on the table are allowed meanwhile. Another difference is that a regular `CREATE INDEX` command can be performed within a transaction block, but `CREATE INDEX CONCURRENTLY` cannot.

Notes

See Chapter 11 for information about when indexes can be used, when they are not used, and in which particular situations they can be useful.

Caution

Hash index operations are not presently WAL-logged, so hash indexes might need to be rebuilt with REINDEX after a database crash if there were unwritten changes. Also, changes to hash indexes are not replicated over streaming or file-based replication after the initial base backup, so they give wrong answers to queries that subsequently use them. For these reasons, hash index use is presently discouraged.

Currently, only the B-tree, GiST and GIN index methods support multicolumn indexes. Up to 32 fields can be specified by default. (This limit can be altered when building PostgreSQL.) Only B-tree currently supports unique indexes.

An *operator class* can be specified for each column of an index. The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on four-byte integers would use the int4_ops class; this operator class includes comparison functions for four-byte integers. In practice the default operator class for the column's data type is usually sufficient. The main point of having operator classes is that for some data types, there could be more than one meaningful ordering. For example, we might want to sort a complex-number data type either by absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when making an index. More information about operator classes is in Section 11.9 and in Section 35.14.

For index methods that support ordered scans (currently, only B-tree), the optional clauses ASC, DESC, NULLS FIRST, and/or NULLS LAST can be specified to modify the sort ordering of the index. Since an ordered index can be scanned either forward or backward, it is not normally useful to create a single-column DESC index — that sort ordering is already available with a regular index. The value of these options is that multicolumn indexes can be created that match the sort ordering requested by a mixed-ordering query, such as SELECT ... ORDER BY x ASC, y DESC. The NULLS options are useful if you need to support "nulls sort low" behavior, rather than the default "nulls sort high", in queries that depend on indexes to avoid sorting steps.

For most index methods, the speed of creating an index is dependent on the setting of maintenance_work_mem. Larger values will reduce the time needed for index creation, so long as you don't make it larger than the amount of memory really available, which would drive the machine into swapping. For hash indexes, the value of effective_cache_size is also relevant to index creation time: PostgreSQL will use one of two different hash index creation methods depending on whether the estimated index size is more or less than effective_cache_size. For best results, make sure that this parameter is also set to something reflective of available memory, and be careful that the sum of maintenance_work_mem and effective_cache_size is less than the machine's RAM less whatever space is needed by other programs.

Use DROP INDEX to remove an index.

Prior releases of PostgreSQL also had an R-tree index method. This method has been removed because it had no significant advantages over the GiST method. If USING rtree is specified, CREATE INDEX will interpret it as USING gist, to simplify conversion of old databases to GiST.

Examples

To create a B-tree index on the column `title` in the table `films`:

```
CREATE UNIQUE INDEX title_idx ON films (title);
```

To create an index on the expression `lower(title)`, allowing efficient case-insensitive searches:

```
CREATE INDEX ON films ((lower(title)));
```

(In this example we have chosen to omit the index name, so the system will choose a name, typically `films_lower_idx`.)

To create an index with non-default collation:

```
CREATE INDEX title_idx_german ON films (title COLLATE "de_DE");
```

To create an index with non-default sort ordering of nulls:

```
CREATE INDEX title_idx_nulls_low ON films (title NULLS FIRST);
```

To create an index with non-default fill factor:

```
CREATE UNIQUE INDEX title_idx ON films (title) WITH (fillfactor = 70);
```

To create a GIN index with fast updates disabled:

```
CREATE INDEX gin_idx ON documents_table USING gin (locations) WITH (fastupdate = off);
```

To create an index on the column `code` in the table `films` and have the index reside in the tablespace `indexspace`:

```
CREATE INDEX code_idx ON films (code) TABLESPACE indexspace;
```

To create a GiST index on a point attribute so that we can efficiently use box operators on the result of the conversion function:

```
CREATE INDEX pointloc
    ON points USING gist (box(location,location));
SELECT * FROM points
    WHERE box(location,location) && '(0,0),(1,1)'::box;
```

To create an index without locking out writes to the table:

```
CREATE INDEX CONCURRENTLY sales_quantity_index ON sales_table (quantity);
```

Compatibility

`CREATE INDEX` is a PostgreSQL language extension. There are no provisions for indexes in the SQL standard.

See Also

ALTER INDEX, DROP INDEX

CREATE LANGUAGE

Name

CREATE LANGUAGE — define a new procedural language

Synopsis

```
CREATE [ OR REPLACE ] [ PROCEDURAL ] LANGUAGE name
CREATE [ OR REPLACE ] [ TRUSTED ] [ PROCEDURAL ] LANGUAGE name
    HANDLER call_handler [ INLINE inline_handler ] [ VALIDATOR valfunction ]
```

Description

CREATE LANGUAGE registers a new procedural language with a PostgreSQL database. Subsequently, functions and trigger procedures can be defined in this new language.

> **Note:** As of PostgreSQL 9.1, most procedural languages have been made into "extensions", and should therefore be installed with CREATE EXTENSION not CREATE LANGUAGE. Direct use of CREATE LANGUAGE should now be confined to extension installation scripts. If you have a "bare" language in your database, perhaps as a result of an upgrade, you can convert it to an extension using CREATE EXTENSION *langname* FROM unpackaged.

CREATE LANGUAGE effectively associates the language name with handler function(s) that are responsible for executing functions written in the language. Refer to Chapter 52 for more information about language handlers.

There are two forms of the CREATE LANGUAGE command. In the first form, the user supplies just the name of the desired language, and the PostgreSQL server consults the pg_pltemplate system catalog to determine the correct parameters. In the second form, the user supplies the language parameters along with the language name. The second form can be used to create a language that is not defined in pg_pltemplate, but this approach is considered obsolescent.

When the server finds an entry in the pg_pltemplate catalog for the given language name, it will use the catalog data even if the command includes language parameters. This behavior simplifies loading of old dump files, which are likely to contain out-of-date information about language support functions.

Ordinarily, the user must have the PostgreSQL superuser privilege to register a new language. However, the owner of a database can register a new language within that database if the language is listed in the pg_pltemplate catalog and is marked as allowed to be created by database owners (tmpldbacreate is true). The default is that trusted languages can be created by database owners, but this can be adjusted by superusers by modifying the contents of pg_pltemplate. The creator of a language becomes its owner and can later drop it, rename it, or assign it to a new owner.

CREATE OR REPLACE LANGUAGE will either create a new language, or replace an existing definition. If the language already exists, its parameters are updated according to the values specified or taken from pg_pltemplate, but the language's ownership and permissions settings do not change, and any existing functions written in the language are assumed to still be valid. In addition to the normal privilege requirements for creating a language, the user must be superuser or owner of the existing language. The REPLACE case is mainly meant to be used to ensure that the language exists. If the

language has a `pg_pltemplate` entry then `REPLACE` will not actually change anything about an existing definition, except in the unusual case where the `pg_pltemplate` entry has been modified since the language was created.

Parameters

`TRUSTED`

`TRUSTED` specifies that the language does not grant access to data that the user would not otherwise have. If this key word is omitted when registering the language, only users with the PostgreSQL superuser privilege can use this language to create new functions.

`PROCEDURAL`

This is a noise word.

`name`

The name of the new procedural language. The name must be unique among the languages in the database.

For backward compatibility, the name can be enclosed by single quotes.

`HANDLER` *`call_handler`*

`call_handler` is the name of a previously registered function that will be called to execute the procedural language's functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with PostgreSQL as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

`INLINE` *`inline_handler`*

`inline_handler` is the name of a previously registered function that will be called to execute an anonymous code block (DO command) in this language. If no *`inline_handler`* function is specified, the language does not support anonymous code blocks. The handler function must take one argument of type `internal`, which will be the `DO` command's internal representation, and it will typically return `void`. The return value of the handler is ignored.

`VALIDATOR` *`valfunction`*

`valfunction` is the name of a previously registered function that will be called when a new function in the language is created, to validate the new function. If no validator function is specified, then a new function will not be checked when it is created. The validator function must take one argument of type `oid`, which will be the OID of the to-be-created function, and will typically return `void`.

A validator function would typically inspect the function body for syntactical correctness, but it can also look at other properties of the function, for example if the language cannot handle certain argument types. To signal an error, the validator function should use the `ereport()` function. The return value of the function is ignored.

The `TRUSTED` option and the support function name(s) are ignored if the server has an entry for the specified language name in `pg_pltemplate`.

Notes

The createlang program is a simple wrapper around the CREATE LANGUAGE command. It eases installation of procedural languages from the shell command line.

Use DROP LANGUAGE, or better yet the droplang program, to drop procedural languages.

The system catalog pg_language (see Section 48.28) records information about the currently installed languages. Also, createlang has an option to list the installed languages.

To create functions in a procedural language, a user must have the USAGE privilege for the language. By default, USAGE is granted to PUBLIC (i.e., everyone) for trusted languages. This can be revoked if desired.

Procedural languages are local to individual databases. However, a language can be installed into the template1 database, which will cause it to be available automatically in all subsequently-created databases.

The call handler function, the inline handler function (if any), and the validator function (if any) must already exist if the server does not have an entry for the language in pg_pltemplate. But when there is an entry, the functions need not already exist; they will be automatically defined if not present in the database. (This might result in CREATE LANGUAGE failing, if the shared library that implements the language is not available in the installation.)

In PostgreSQL versions before 7.3, it was necessary to declare handler functions as returning the placeholder type opaque, rather than language_handler. To support loading of old dump files, CREATE LANGUAGE will accept a function declared as returning opaque, but it will issue a notice and change the function's declared return type to language_handler.

Examples

The preferred way of creating any of the standard procedural languages is just:

```
CREATE LANGUAGE plperl;
```

For a language not known in the pg_pltemplate catalog, a sequence such as this is needed:

```
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
    AS '$libdir/plsample'
    LANGUAGE C;
CREATE LANGUAGE plsample
    HANDLER plsample_call_handler;
```

Compatibility

CREATE LANGUAGE is a PostgreSQL extension.

See Also

ALTER LANGUAGE, CREATE FUNCTION, DROP LANGUAGE, GRANT, REVOKE, createlang, droplang

CREATE MATERIALIZED VIEW

Name

CREATE MATERIALIZED VIEW — define a new materialized view

Synopsis

```
CREATE MATERIALIZED VIEW table_name
    [ (column_name [, ...] ) ]
    [ WITH ( storage_parameter [= value] [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    AS query
    [ WITH [ NO ] DATA ]
```

Description

CREATE MATERIALIZED VIEW defines a materialized view of a query. The query is executed and used to populate the view at the time the command is issued (unless WITH NO DATA is used) and may be refreshed later using REFRESH MATERIALIZED VIEW.

CREATE MATERIALIZED VIEW is similar to CREATE TABLE AS, except that it also remembers the query used to initialize the view, so that it can be refreshed later upon demand. A materialized view has many of the same properties as a table, but there is no support for temporary materialized views or automatic generation of OIDs.

Parameters

table_name

The name (optionally schema-qualified) of the materialized view to be created.

column_name

The name of a column in the new materialized view. If column names are not provided, they are taken from the output column names of the query.

WITH (*storage_parameter* [= *value*] [, ...])

This clause specifies optional storage parameters for the new materialized view; see *Storage Parameters* for more information. All parameters supported for CREATE TABLE are also supported for CREATE MATERIALIZED VIEW with the exception of OIDS. See CREATE TABLE for more information.

TABLESPACE *tablespace_name*

The *tablespace_name* is the name of the tablespace in which the new materialized view is to be created. If not specified, default_tablespace is consulted.

query

A SELECT, TABLE, or VALUES command. This query will run within a security-restricted operation; in particular, calls to functions that themselves create temporary tables will fail.

`WITH [ NO ] DATA`

This clause specifies whether or not the materialized view should be populated at creation time. If not, the materialized view will be flagged as unscannable and cannot be queried until `REFRESH MATERIALIZED VIEW` is used.

Compatibility

`CREATE MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

ALTER MATERIALIZED VIEW, CREATE TABLE AS, CREATE VIEW, DROP MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

CREATE OPERATOR

Name

CREATE OPERATOR — define a new operator

Synopsis

```
CREATE OPERATOR name (
    PROCEDURE = function_name
    [, LEFTARG = left_type ] [, RIGHTARG = right_type ]
    [, COMMUTATOR = com_op ] [, NEGATOR = neg_op ]
    [, RESTRICT = res_proc ] [, JOIN = join_proc ]
    [, HASHES ] [, MERGES ]
)
```

Description

CREATE OPERATOR defines a new operator, *name*. The user who defines an operator becomes its owner. If a schema name is given then the operator is created in the specified schema. Otherwise it is created in the current schema.

The operator name is a sequence of up to NAMEDATALEN-1 (63 by default) characters from the following list:

+ - * / < > = ~ ! @ # % ^ & | ` ?

There are a few restrictions on your choice of name:

- -- and /* cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multicharacter operator name cannot end in + or -, unless the name also contains at least one of these characters:

  ~ ! @ # % ^ & | ` ?

  For example, @- is an allowed operator name, but *- is not. This restriction allows PostgreSQL to parse SQL-compliant commands without requiring spaces between tokens.
- The use of => as an operator name is deprecated. It may be disallowed altogether in a future release.

The operator != is mapped to <> on input, so these two names are always equivalent.

At least one of LEFTARG and RIGHTARG must be defined. For binary operators, both must be defined. For right unary operators, only LEFTARG should be defined, while for left unary operators only RIGHTARG should be defined.

The *function_name* procedure must have been previously defined using CREATE FUNCTION and must be defined to accept the correct number of arguments (either one or two) of the indicated types.

The other clauses specify optional operator optimization clauses. Their meaning is detailed in Section 35.13.

To be able to create an operator, you must have `USAGE` privilege on the argument types and the return type, as well as `EXECUTE` privilege on the underlying function. If a commutator or negator operator is specified, you must own these operators.

Parameters

name

The name of the operator to be defined. See above for allowable characters. The name can be schema-qualified, for example `CREATE OPERATOR myschema.+ (...)`. If not, then the operator is created in the current schema. Two operators in the same schema can have the same name if they operate on different data types. This is called *overloading*.

function_name

The function used to implement this operator.

left_type

The data type of the operator's left operand, if any. This option would be omitted for a left-unary operator.

right_type

The data type of the operator's right operand, if any. This option would be omitted for a right-unary operator.

com_op

The commutator of this operator.

neg_op

The negator of this operator.

res_proc

The restriction selectivity estimator function for this operator.

join_proc

The join selectivity estimator function for this operator.

`HASHES`

Indicates this operator can support a hash join.

`MERGES`

Indicates this operator can support a merge join.

To give a schema-qualified operator name in *com_op* or the other optional arguments, use the `OPERATOR()` syntax, for example:

```
COMMUTATOR = OPERATOR(myschema.===) ,
```

Notes

Refer to Section 35.12 for further information.

It is not possible to specify an operator's lexical precedence in `CREATE OPERATOR`, because the parser's precedence behavior is hard-wired. See Section 4.1.6 for precedence details.

The obsolete options `SORT1`, `SORT2`, `LTCMP`, and `GTCMP` were formerly used to specify the names of sort operators associated with a merge-joinable operator. This is no longer necessary, since information about associated operators is found by looking at B-tree operator families instead. If one of these options is given, it is ignored except for implicitly setting `MERGES` true.

Use DROP OPERATOR to delete user-defined operators from a database. Use ALTER OPERATOR to modify operators in a database.

Examples

The following command defines a new operator, area-equality, for the data type `box`:

```
CREATE OPERATOR === (
    LEFTARG = box,
    RIGHTARG = box,
    PROCEDURE = area_equal_procedure,
    COMMUTATOR = ===,
    NEGATOR = !==,
    RESTRICT = area_restriction_procedure,
    JOIN = area_join_procedure,
    HASHES, MERGES
);
```

Compatibility

`CREATE OPERATOR` is a PostgreSQL extension. There are no provisions for user-defined operators in the SQL standard.

See Also

ALTER OPERATOR, CREATE OPERATOR CLASS, DROP OPERATOR

CREATE OPERATOR CLASS

Name

CREATE OPERATOR CLASS — define a new operator class

Synopsis

```
CREATE OPERATOR CLASS name [ DEFAULT ] FOR TYPE data_type
  USING index_method [ FAMILY family_name ] AS
  {  OPERATOR strategy_number operator_name [ ( op_type, op_type ) ] [ FOR SEARCH | FOR ORDE
   | FUNCTION support_number [ ( op_type [ , op_type ] ) ] function_name ( argument_type [, .
   | STORAGE storage_type
  } [, ... ]
```

Description

CREATE OPERATOR CLASS creates a new operator class. An operator class defines how a particular data type can be used with an index. The operator class specifies that certain operators will fill particular roles or "strategies" for this data type and this index method. The operator class also specifies the support procedures to be used by the index method when the operator class is selected for an index column. All the operators and functions used by an operator class must be defined before the operator class can be created.

If a schema name is given then the operator class is created in the specified schema. Otherwise it is created in the current schema. Two operator classes in the same schema can have the same name only if they are for different index methods.

The user who defines an operator class becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator class definition could confuse or even crash the server.)

CREATE OPERATOR CLASS does not presently check whether the operator class definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator class.

Related operator classes can be grouped into *operator families*. To add a new operator class to an existing family, specify the FAMILY option in CREATE OPERATOR CLASS. Without this option, the new class is placed into a family named the same as the new class (creating that family if it doesn't already exist).

Refer to Section 35.14 for further information.

Parameters

name

The name of the operator class to be created. The name can be schema-qualified.

DEFAULT

If present, the operator class will become the default operator class for its data type. At most one operator class can be the default for a specific data type and index method.

data_type

The column data type that this operator class is for.

index_method

The name of the index method this operator class is for.

family_name

The name of the existing operator family to add this operator class to. If not specified, a family named the same as the operator class is used (creating it, if it doesn't already exist).

strategy_number

The index method's strategy number for an operator associated with the operator class.

operator_name

The name (optionally schema-qualified) of an operator associated with the operator class.

op_type

In an `OPERATOR` clause, the operand data type(s) of the operator, or `NONE` to signify a left-unary or right-unary operator. The operand data types can be omitted in the normal case where they are the same as the operator class's data type.

In a `FUNCTION` clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function (for B-tree comparison functions and hash functions) or the class's data type (for B-tree sort support functions and all functions in GiST, SP-GiST and GIN operator classes). These defaults are correct, and so *op_type* need not be specified in `FUNCTION` clauses, except for the case of a B-tree sort support function that is meant to support cross-data-type comparisons.

sort_family_name

The name (optionally schema-qualified) of an existing `btree` operator family that describes the sort ordering associated with an ordering operator.

If neither `FOR SEARCH` nor `FOR ORDER BY` is specified, `FOR SEARCH` is the default.

support_number

The index method's support procedure number for a function associated with the operator class.

function_name

The name (optionally schema-qualified) of a function that is an index method support procedure for the operator class.

argument_type

The parameter data type(s) of the function.

storage_type

The data type actually stored in the index. Normally this is the same as the column data type, but some index methods (currently GiST and GIN) allow it to be different. The `STORAGE` clause must be omitted unless the index method allows a different type to be used.

The `OPERATOR`, `FUNCTION`, and `STORAGE` clauses can appear in any order.

Notes

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator class is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator class.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Before PostgreSQL 8.4, the `OPERATOR` clause could include a `RECHECK` option. This is no longer supported because whether an index operator is "lossy" is now determined on-the-fly at run time. This allows efficient handling of cases where an operator might or might not be lossy.

Examples

The following example command defines a GiST index operator class for the data type `_int4` (array of `int4`). See the intarray module for the complete example.

```
CREATE OPERATOR CLASS gist__int_ops
    DEFAULT FOR TYPE _int4 USING gist AS
        OPERATOR        3       &&,
        OPERATOR        6       = (anyarray, anyarray),
        OPERATOR        7       @>,
        OPERATOR        8       <@,
        OPERATOR        20      @@ (_int4, query_int),
        FUNCTION        1       g_int_consistent (internal, _int4, int, oid, internal),
        FUNCTION        2       g_int_union (internal, internal),
        FUNCTION        3       g_int_compress (internal),
        FUNCTION        4       g_int_decompress (internal),
        FUNCTION        5       g_int_penalty (internal, internal, internal),
        FUNCTION        6       g_int_picksplit (internal, internal),
        FUNCTION        7       g_int_same (_int4, _int4, internal);
```

Compatibility

`CREATE OPERATOR CLASS` is a PostgreSQL extension. There is no `CREATE OPERATOR CLASS` statement in the SQL standard.

See Also

ALTER OPERATOR CLASS, DROP OPERATOR CLASS, CREATE OPERATOR FAMILY, ALTER OPERATOR FAMILY

CREATE OPERATOR FAMILY

Name

CREATE OPERATOR FAMILY — define a new operator family

Synopsis

```
CREATE OPERATOR FAMILY name USING index_method
```

Description

CREATE OPERATOR FAMILY creates a new operator family. An operator family defines a collection of related operator classes, and perhaps some additional operators and support functions that are compatible with these operator classes but not essential for the functioning of any individual index. (Operators and functions that are essential to indexes should be grouped within the relevant operator class, rather than being "loose" in the operator family. Typically, single-data-type operators are bound to operator classes, while cross-data-type operators can be loose in an operator family containing operator classes for both data types.)

The new operator family is initially empty. It should be populated by issuing subsequent CREATE OPERATOR CLASS commands to add contained operator classes, and optionally ALTER OPERATOR FAMILY commands to add "loose" operators and their corresponding support functions.

If a schema name is given then the operator family is created in the specified schema. Otherwise it is created in the current schema. Two operator families in the same schema can have the same name only if they are for different index methods.

The user who defines an operator family becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

Refer to Section 35.14 for further information.

Parameters

name

The name of the operator family to be created. The name can be schema-qualified.

index_method

The name of the index method this operator family is for.

Compatibility

CREATE OPERATOR FAMILY is a PostgreSQL extension. There is no CREATE OPERATOR FAMILY statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, DROP OPERATOR FAMILY, CREATE OPERATOR CLASS, ALTER OPERATOR CLASS, DROP OPERATOR CLASS

CREATE ROLE

Name

CREATE ROLE — define a new database role

Synopsis

```
CREATE ROLE name [ [ WITH ] option [ ... ] ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEUSER | NOCREATEUSER
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | CONNECTION LIMIT connlimit
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
    | VALID UNTIL 'timestamp'
    | IN ROLE role_name [, ...]
    | IN GROUP role_name [, ...]
    | ROLE role_name [, ...]
    | ADMIN role_name [, ...]
    | USER role_name [, ...]
    | SYSID uid
```

Description

CREATE ROLE adds a new role to a PostgreSQL database cluster. A role is an entity that can own database objects and have database privileges; a role can be considered a "user", a "group", or both depending on how it is used. Refer to Chapter 20 and Chapter 19 for information about managing users and authentication. You must have CREATEROLE privilege or be a database superuser to use this command.

Note that roles are defined at the database cluster level, and so are valid in all databases in the cluster.

Parameters

name

The name of the new role.

SUPERUSER
NOSUPERUSER

These clauses determine whether the new role is a "superuser", who can override all access restrictions within the database. Superuser status is dangerous and should be used only when really needed. You must yourself be a superuser to create a new superuser. If not specified, NOSUPERUSER is the default.

`CREATEDB`
`NOCREATEDB`

These clauses define a role's ability to create databases. If `CREATEDB` is specified, the role being defined will be allowed to create new databases. Specifying `NOCREATEDB` will deny a role the ability to create databases. If not specified, `NOCREATEDB` is the default.

`CREATEROLE`
`NOCREATEROLE`

These clauses determine whether a role will be permitted to create new roles (that is, execute `CREATE ROLE`). A role with `CREATEROLE` privilege can also alter and drop other roles. If not specified, `NOCREATEROLE` is the default.

`CREATEUSER`
`NOCREATEUSER`

These clauses are an obsolete, but still accepted, spelling of `SUPERUSER` and `NOSUPERUSER`. Note that they are *not* equivalent to `CREATEROLE` as one might naively expect!

`INHERIT`
`NOINHERIT`

These clauses determine whether a role "inherits" the privileges of roles it is a member of. A role with the `INHERIT` attribute can automatically use whatever database privileges have been granted to all roles it is directly or indirectly a member of. Without `INHERIT`, membership in another role only grants the ability to `SET ROLE` to that other role; the privileges of the other role are only available after having done so. If not specified, `INHERIT` is the default.

`LOGIN`
`NOLOGIN`

These clauses determine whether a role is allowed to log in; that is, whether the role can be given as the initial session authorization name during client connection. A role having the `LOGIN` attribute can be thought of as a user. Roles without this attribute are useful for managing database privileges, but are not users in the usual sense of the word. If not specified, `NOLOGIN` is the default, except when `CREATE ROLE` is invoked through its alternative spelling CREATE USER.

`REPLICATION`
`NOREPLICATION`

These clauses determine whether a role is allowed to initiate streaming replication or put the system in and out of backup mode. A role having the `REPLICATION` attribute is a very highly privileged role, and should only be used on roles actually used for replication. If not specified, `NOREPLICATION` is the default.

`CONNECTION LIMIT` *`connlimit`*

If role can log in, this specifies how many concurrent connections the role can make. -1 (the default) means no limit.

`PASSWORD` *`password`*

Sets the role's password. (A password is only of use for roles having the `LOGIN` attribute, but you can nonetheless define one for roles without it.) If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as `PASSWORD NULL`.

`ENCRYPTED`
`UNENCRYPTED`

These key words control whether the password is stored encrypted in the system catalogs. (If neither is specified, the default behavior is determined by the configuration parameter password_encryption.) If the presented password string is already in MD5-encrypted format, then it is stored encrypted as-is, regardless of whether `ENCRYPTED` or `UNENCRYPTED` is specified (since the system cannot decrypt the specified encrypted password string). This allows reloading of encrypted passwords during dump/restore.

Note that older clients might lack support for the MD5 authentication mechanism that is needed to work with passwords that are stored encrypted.

`VALID UNTIL '`*`timestamp`*`'`

The `VALID UNTIL` clause sets a date and time after which the role's password is no longer valid. If this clause is omitted the password will be valid for all time.

`IN ROLE` *`role_name`*

The `IN ROLE` clause lists one or more existing roles to which the new role will be immediately added as a new member. (Note that there is no option to add the new role as an administrator; use a separate `GRANT` command to do that.)

`IN GROUP` *`role_name`*

`IN GROUP` is an obsolete spelling of `IN ROLE`.

`ROLE` *`role_name`*

The `ROLE` clause lists one or more existing roles which are automatically added as members of the new role. (This in effect makes the new role a "group".)

`ADMIN` *`role_name`*

The `ADMIN` clause is like `ROLE`, but the named roles are added to the new role `WITH ADMIN OPTION`, giving them the right to grant membership in this role to others.

`USER` *`role_name`*

The `USER` clause is an obsolete spelling of the `ROLE` clause.

`SYSID` *`uid`*

The `SYSID` clause is ignored, but is accepted for backwards compatibility.

Notes

Use ALTER ROLE to change the attributes of a role, and DROP ROLE to remove a role. All the attributes specified by `CREATE ROLE` can be modified by later `ALTER ROLE` commands.

The preferred way to add and remove members of roles that are being used as groups is to use GRANT and REVOKE.

The `VALID UNTIL` clause defines an expiration time for a password only, not for the role *per se*. In particular, the expiration time is not enforced when logging in using a non-password-based authentication method.

The `INHERIT` attribute governs inheritance of grantable privileges (that is, access privileges for database objects and role memberships). It does not apply to the special role attributes set by `CREATE ROLE` and `ALTER ROLE`. For example, being a member of a role with `CREATEDB` privilege does not

immediately grant the ability to create databases, even if INHERIT is set; it would be necessary to become that role via SET ROLE before creating a database.

The INHERIT attribute is the default for reasons of backwards compatibility: in prior releases of PostgreSQL, users always had access to all privileges of groups they were members of. However, NOINHERIT provides a closer match to the semantics specified in the SQL standard.

Be careful with the CREATEROLE privilege. There is no concept of inheritance for the privileges of a CREATEROLE-role. That means that even if a role does not have a certain privilege but is allowed to create other roles, it can easily create another role with different privileges than its own (except for creating roles with superuser privileges). For example, if the role "user" has the CREATEROLE privilege but not the CREATEDB privilege, nonetheless it can create a new role with the CREATEDB privilege. Therefore, regard roles that have the CREATEROLE privilege as almost-superuser-roles.

PostgreSQL includes a program createuser that has the same functionality as CREATE ROLE (in fact, it calls this command) but can be run from the command shell.

The CONNECTION LIMIT option is only enforced approximately; if two new sessions start at about the same time when just one connection "slot" remains for the role, it is possible that both will fail. Also, the limit is never enforced for superusers.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in cleartext, and it might also be logged in the client's command history or the server log. The command createuser, however, transmits the password encrypted. Also, psql contains a command \password that can be used to safely change the password later.

Examples

Create a role that can log in, but don't give it a password:

```
CREATE ROLE jonathan LOGIN;
```

Create a role with a password:

```
CREATE USER davide WITH PASSWORD 'jw8s0F4';
```

(CREATE USER is the same as CREATE ROLE except that it implies LOGIN.)

Create a role with a password that is valid until the end of 2004. After one second has ticked in 2005, the password is no longer valid.

```
CREATE ROLE miriam WITH LOGIN PASSWORD 'jw8s0F4' VALID UNTIL '2005-01-01';
```

Create a role that can create databases and manage roles:

```
CREATE ROLE admin WITH CREATEDB CREATEROLE;
```

Compatibility

The `CREATE ROLE` statement is in the SQL standard, but the standard only requires the syntax

```
CREATE ROLE name [ WITH ADMIN role_name ]
```

Multiple initial administrators, and all the other options of `CREATE ROLE`, are PostgreSQL extensions.

The SQL standard defines the concepts of users and roles, but it regards them as distinct concepts and leaves all commands defining users to be specified by each database implementation. In PostgreSQL we have chosen to unify users and roles into a single kind of entity. Roles therefore have many more optional attributes than they do in the standard.

The behavior specified by the SQL standard is most closely approximated by giving users the `NOINHERIT` attribute, while roles are given the `INHERIT` attribute.

See Also

SET ROLE, ALTER ROLE, DROP ROLE, GRANT, REVOKE, createuser

CREATE RULE

Name

CREATE RULE — define a new rewrite rule

Synopsis

```
CREATE [ OR REPLACE ] RULE name AS ON event
    TO table_name [ WHERE condition ]
    DO [ ALSO | INSTEAD ] { NOTHING | command | ( command ; command ... ) }

where event can be one of:

    SELECT | INSERT | UPDATE | DELETE
```

Description

CREATE RULE defines a new rule applying to a specified table or view. CREATE OR REPLACE RULE will either create a new rule, or replace an existing rule of the same name for the same table.

The PostgreSQL rule system allows one to define an alternative action to be performed on insertions, updates, or deletions in database tables. Roughly speaking, a rule causes additional commands to be executed when a given command on a given table is executed. Alternatively, an INSTEAD rule can replace a given command by another, or cause a command not to be executed at all. Rules are used to implement SQL views as well. It is important to realize that a rule is really a command transformation mechanism, or command macro. The transformation happens before the execution of the command starts. If you actually want an operation that fires independently for each physical row, you probably want to use a trigger, not a rule. More information about the rules system is in Chapter 38.

Presently, ON SELECT rules must be unconditional INSTEAD rules and must have actions that consist of a single SELECT command. Thus, an ON SELECT rule effectively turns the table into a view, whose visible contents are the rows returned by the rule's SELECT command rather than whatever had been stored in the table (if anything). It is considered better style to write a CREATE VIEW command than to create a real table and define an ON SELECT rule for it.

You can create the illusion of an updatable view by defining ON INSERT, ON UPDATE, and ON DELETE rules (or any subset of those that's sufficient for your purposes) to replace update actions on the view with appropriate updates on other tables. If you want to support INSERT RETURNING and so on, then be sure to put a suitable RETURNING clause into each of these rules.

There is a catch if you try to use conditional rules for complex view updates: there *must* be an unconditional INSTEAD rule for each action you wish to allow on the view. If the rule is conditional, or is not INSTEAD, then the system will still reject attempts to perform the update action, because it thinks it might end up trying to perform the action on the dummy table of the view in some cases. If you want to handle all the useful cases in conditional rules, add an unconditional DO INSTEAD NOTHING rule to ensure that the system understands it will never be called on to update the dummy table. Then make the conditional rules non-INSTEAD; in the cases where they are applied, they add to the default INSTEAD NOTHING action. (This method does not currently work to support RETURNING queries, however.)

Note: A view that is simple enough to be automatically updatable (see CREATE VIEW) does not require a user-created rule in order to be updatable. While you can create an explicit rule anyway, the automatic update transformation will generally outperform an explicit rule.

Another alternative worth considering is to use `INSTEAD OF` triggers (see CREATE TRIGGER) in place of rules.

Parameters

name

The name of a rule to create. This must be distinct from the name of any other rule for the same table. Multiple rules on the same table and same event type are applied in alphabetical name order.

event

The event is one of `SELECT`, `INSERT`, `UPDATE`, or `DELETE`.

table_name

The name (optionally schema-qualified) of the table or view the rule applies to.

condition

Any SQL conditional expression (returning `boolean`). The condition expression cannot refer to any tables except `NEW` and `OLD`, and cannot contain aggregate functions.

`INSTEAD`

`INSTEAD` indicates that the commands should be executed *instead of* the original command.

`ALSO`

`ALSO` indicates that the commands should be executed *in addition to* the original command.

If neither `ALSO` nor `INSTEAD` is specified, `ALSO` is the default.

command

The command or commands that make up the rule action. Valid commands are `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `NOTIFY`.

Within *condition* and *command*, the special table names `NEW` and `OLD` can be used to refer to values in the referenced table. `NEW` is valid in `ON INSERT` and `ON UPDATE` rules to refer to the new row being inserted or updated. `OLD` is valid in `ON UPDATE` and `ON DELETE` rules to refer to the existing row being updated or deleted.

Notes

You must be the owner of a table to create or change rules for it.

In a rule for `INSERT`, `UPDATE`, or `DELETE` on a view, you can add a `RETURNING` clause that emits the view's columns. This clause will be used to compute the outputs if the rule is triggered by an `INSERT RETURNING`, `UPDATE RETURNING`, or `DELETE RETURNING` command respectively. When the rule is triggered by a command without `RETURNING`, the rule's `RETURNING` clause will be ignored. The current implementation allows only unconditional `INSTEAD` rules to contain `RETURNING`; furthermore there can be at most one `RETURNING` clause among all the rules for the same event. (This ensures that

there is only one candidate RETURNING clause to be used to compute the results.) RETURNING queries on the view will be rejected if there is no RETURNING clause in any available rule.

It is very important to take care to avoid circular rules. For example, though each of the following two rule definitions are accepted by PostgreSQL, the SELECT command would cause PostgreSQL to report an error because of recursive expansion of a rule:

```
CREATE RULE "_RETURN" AS
    ON SELECT TO t1
    DO INSTEAD
        SELECT * FROM t2;

CREATE RULE "_RETURN" AS
    ON SELECT TO t2
    DO INSTEAD
        SELECT * FROM t1;

SELECT * FROM t1;
```

Presently, if a rule action contains a NOTIFY command, the NOTIFY command will be executed unconditionally, that is, the NOTIFY will be issued even if there are not any rows that the rule should apply to. For example, in:

```
CREATE RULE notify_me AS ON UPDATE TO mytable DO ALSO NOTIFY mytable;

UPDATE mytable SET name = 'foo' WHERE id = 42;
```

one NOTIFY event will be sent during the UPDATE, whether or not there are any rows that match the condition `id = 42`. This is an implementation restriction that might be fixed in future releases.

Compatibility

CREATE RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

ALTER RULE, DROP RULE

CREATE SCHEMA

Name

CREATE SCHEMA — define a new schema

Synopsis

```
CREATE SCHEMA schema_name [ AUTHORIZATION user_name ] [ schema_element [ ... ] ]
CREATE SCHEMA AUTHORIZATION user_name [ schema_element [ ... ] ]
CREATE SCHEMA IF NOT EXISTS schema_name [ AUTHORIZATION user_name ]
CREATE SCHEMA IF NOT EXISTS AUTHORIZATION user_name
```

Description

CREATE SCHEMA enters a new schema into the current database. The schema name must be distinct from the name of any existing schema in the current database.

A schema is essentially a namespace: it contains named objects (tables, data types, functions, and operators) whose names can duplicate those of other objects existing in other schemas. Named objects are accessed either by "qualifying" their names with the schema name as a prefix, or by setting a search path that includes the desired schema(s). A CREATE command specifying an unqualified object name creates the object in the current schema (the one at the front of the search path, which can be determined with the function current_schema).

Optionally, CREATE SCHEMA can include subcommands to create objects within the new schema. The subcommands are treated essentially the same as separate commands issued after creating the schema, except that if the AUTHORIZATION clause is used, all the created objects will be owned by that user.

Parameters

schema_name

The name of a schema to be created. If this is omitted, the *user_name* is used as the schema name. The name cannot begin with pg_, as such names are reserved for system schemas.

user_name

The role name of the user who will own the new schema. If omitted, defaults to the user executing the command. To create a schema owned by another role, you must be a direct or indirect member of that role, or be a superuser.

schema_element

An SQL statement defining an object to be created within the schema. Currently, only CREATE TABLE, CREATE VIEW, CREATE INDEX, CREATE SEQUENCE, CREATE TRIGGER and GRANT are accepted as clauses within CREATE SCHEMA. Other kinds of objects may be created in separate commands after the schema is created.

IF NOT EXISTS

Do nothing (except issuing a notice) if a schema with the same name already exists. *schema_element* subcommands cannot be included when this option is used.

Notes

To create a schema, the invoking user must have the `CREATE` privilege for the current database. (Of course, superusers bypass this check.)

Examples

Create a schema:

```
CREATE SCHEMA myschema;
```

Create a schema for user `joe`; the schema will also be named `joe`:

```
CREATE SCHEMA AUTHORIZATION joe;
```

Create a schema named `test` that will be owned by user `joe`, unless there already is a schema named `test`. (It does not matter whether `joe` owns the pre-existing schema.)

```
CREATE SCHEMA IF NOT EXISTS test AUTHORIZATION joe;
```

Create a schema and create a table and view within it:

```
CREATE SCHEMA hollywood
    CREATE TABLE films (title text, release date, awards text[])
    CREATE VIEW winners AS
        SELECT title, release FROM films WHERE awards IS NOT NULL;
```

Notice that the individual subcommands do not end with semicolons.

The following is an equivalent way of accomplishing the same result:

```
CREATE SCHEMA hollywood;
CREATE TABLE hollywood.films (title text, release date, awards text[]);
CREATE VIEW hollywood.winners AS
    SELECT title, release FROM hollywood.films WHERE awards IS NOT NULL;
```

Compatibility

The SQL standard allows a `DEFAULT CHARACTER SET` clause in `CREATE SCHEMA`, as well as more subcommand types than are presently accepted by PostgreSQL.

The SQL standard specifies that the subcommands in `CREATE SCHEMA` can appear in any order. The present PostgreSQL implementation does not handle all cases of forward references in subcommands; it might sometimes be necessary to reorder the subcommands in order to avoid forward references.

According to the SQL standard, the owner of a schema always owns all objects within it. PostgreSQL allows schemas to contain objects owned by users other than the schema owner. This can happen only if the schema owner grants the `CREATE` privilege on his schema to someone else, or a superuser chooses to create objects in it.

The `IF NOT EXISTS` option is a PostgreSQL extension.

See Also

ALTER SCHEMA, DROP SCHEMA

CREATE SEQUENCE

Name

CREATE SEQUENCE — define a new sequence generator

Synopsis

```
CREATE [ TEMPORARY | TEMP ] SEQUENCE name [ INCREMENT [ BY ] increment ]
    [ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO MAXVALUE ]
    [ START [ WITH ] start ] [ CACHE cache ] [ [ NO ] CYCLE ]
    [ OWNED BY { table_name.column_name | NONE } ]
```

Description

CREATE SEQUENCE creates a new sequence number generator. This involves creating and initializing a new special single-row table with the name *name*. The generator will be owned by the user issuing the command.

If a schema name is given then the sequence is created in the specified schema. Otherwise it is created in the current schema. Temporary sequences exist in a special schema, so a schema name cannot be given when creating a temporary sequence. The sequence name must be distinct from the name of any other sequence, table, index, view, or foreign table in the same schema.

After a sequence is created, you use the functions nextval, currval, and setval to operate on the sequence. These functions are documented in Section 9.16.

Although you cannot update a sequence directly, you can use a query like:

```
SELECT * FROM name;
```

to examine the parameters and current state of a sequence. In particular, the last_value field of the sequence shows the last value allocated by any session. (Of course, this value might be obsolete by the time it's printed, if other sessions are actively doing nextval calls.)

Parameters

TEMPORARY or TEMP

If specified, the sequence object is created only for this session, and is automatically dropped on session exit. Existing permanent sequences with the same name are not visible (in this session) while the temporary sequence exists, unless they are referenced with schema-qualified names.

name

The name (optionally schema-qualified) of the sequence to be created.

increment

The optional clause INCREMENT BY *increment* specifies which value is added to the current sequence value to create a new value. A positive value will make an ascending sequence, a negative one a descending sequence. The default value is 1.

minvalue
NO MINVALUE

The optional clause MINVALUE *minvalue* determines the minimum value a sequence can generate. If this clause is not supplied or NO MINVALUE is specified, then defaults will be used. The defaults are 1 and -2^{63}-1 for ascending and descending sequences, respectively.

maxvalue
NO MAXVALUE

The optional clause MAXVALUE *maxvalue* determines the maximum value for the sequence. If this clause is not supplied or NO MAXVALUE is specified, then default values will be used. The defaults are 2^{63}-1 and -1 for ascending and descending sequences, respectively.

start

The optional clause START WITH *start* allows the sequence to begin anywhere. The default starting value is *minvalue* for ascending sequences and *maxvalue* for descending ones.

cache

The optional clause CACHE *cache* specifies how many sequence numbers are to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache), and this is also the default.

CYCLE
NO CYCLE

The CYCLE option allows the sequence to wrap around when the *maxvalue* or *minvalue* has been reached by an ascending or descending sequence respectively. If the limit is reached, the next number generated will be the *minvalue* or *maxvalue*, respectively.

If NO CYCLE is specified, any calls to nextval after the sequence has reached its maximum value will return an error. If neither CYCLE or NO CYCLE are specified, NO CYCLE is the default.

OWNED BY *table_name.column_name*
OWNED BY NONE

The OWNED BY option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. The specified table must have the same owner and be in the same schema as the sequence. OWNED BY NONE, the default, specifies that there is no such association.

Notes

Use DROP SEQUENCE to remove a sequence.

Sequences are based on bigint arithmetic, so the range cannot exceed the range of an eight-byte integer (-9223372036854775808 to 9223372036854775807).

Unexpected results might be obtained if a *cache* setting greater than one is used for a sequence object that will be used concurrently by multiple sessions. Each session will allocate and cache successive sequence values during one access to the sequence object and increase the sequence object's last_value accordingly. Then, the next *cache*-1 uses of nextval within that session simply return the preallocated values without touching the sequence object. So, any numbers allocated but not used within a session will be lost when that session ends, resulting in "holes" in the sequence.

Furthermore, although multiple sessions are guaranteed to allocate distinct sequence values, the values might be generated out of sequence when all the sessions are considered. For example, with a *cache* setting of 10, session A might reserve values 1..10 and return nextval=1, then session B might

reserve values 11..20 and return nextval=11 before session A has generated nextval=2. Thus, with a *cache* setting of one it is safe to assume that nextval values are generated sequentially; with a *cache* setting greater than one you should only assume that the nextval values are all distinct, not that they are generated purely sequentially. Also, last_value will reflect the latest value reserved by any session, whether or not it has yet been returned by nextval.

Another consideration is that a setval executed on such a sequence will not be noticed by other sessions until they have used up any preallocated values they have cached.

Examples

Create an ascending sequence called serial, starting at 101:

```
CREATE SEQUENCE serial START 101;
```

Select the next number from this sequence:

```
SELECT nextval('serial');

 nextval
---------
     101
```

Select the next number from this sequence:

```
SELECT nextval('serial');

 nextval
---------
     102
```

Use this sequence in an INSERT command:

```
INSERT INTO distributors VALUES (nextval('serial'), 'nothing');
```

Update the sequence value after a COPY FROM:

```
BEGIN;
COPY distributors FROM 'input_file';
SELECT setval('serial', max(id)) FROM distributors;
END;
```

Compatibility

`CREATE SEQUENCE` conforms to the SQL standard, with the following exceptions:

- The standard's `AS <data type>` expression is not supported.
- Obtaining the next value is done using the `nextval()` function instead of the standard's `NEXT VALUE FOR` expression.
- The `OWNED BY` clause is a PostgreSQL extension.

See Also

ALTER SEQUENCE, DROP SEQUENCE

CREATE SERVER

Name

CREATE SERVER — define a new foreign server

Synopsis

```
CREATE SERVER server_name [ TYPE 'server_type' ] [ VERSION 'server_version' ]
    FOREIGN DATA WRAPPER fdw_name
    [ OPTIONS ( option 'value' [, ... ] ) ]
```

Description

CREATE SERVER defines a new foreign server. The user who defines the server becomes its owner.

A foreign server typically encapsulates connection information that a foreign-data wrapper uses to access an external data resource. Additional user-specific connection information may be specified by means of user mappings.

The server name must be unique within the database.

Creating a server requires USAGE privilege on the foreign-data wrapper being used.

Parameters

server_name

The name of the foreign server to be created.

server_type

Optional server type, potentially useful to foreign-data wrappers.

server_version

Optional server version, potentially useful to foreign-data wrappers.

fdw_name

The name of the foreign-data wrapper that manages the server.

OPTIONS (*option* '*value*' [, ...])

This clause specifies the options for the server. The options typically define the connection details of the server, but the actual names and values are dependent on the server's foreign-data wrapper.

Notes

When using the dblink module, a foreign server's name can be used as an argument of the dblink_connect function to indicate the connection parameters. It is necessary to have the USAGE privilege on the foreign server to be able to use it in this way.

Examples

Create a server `myserver` that uses the foreign-data wrapper `postgres_fdw`:

```
CREATE SERVER myserver FOREIGN DATA WRAPPER postgres_fdw OPTIONS (host 'foo', dbname 'fo
```

See postgres_fdw for more details.

Compatibility

`CREATE SERVER` conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

ALTER SERVER, DROP SERVER, CREATE FOREIGN DATA WRAPPER, CREATE FOREIGN TABLE, CREATE USER MAPPING

CREATE TABLE

Name

CREATE TABLE — define a new table

Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ] ta
  { column_name data_type [ COLLATE collation ] [ column_constraint [ ... ] ]
    | table_constraint
    | LIKE source_table [ like_option ... ] }
    [, ... ]
] )
[ INHERITS ( parent_table [, ... ] ) ]
[ WITH ( storage_parameter [= value] [, ... ] ) | WITH OIDS | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]

CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ] ta
    OF type_name [ (
  { column_name WITH OPTIONS [ column_constraint [ ... ] ]
    | table_constraint }
    [, ... ]
) ]
[ WITH ( storage_parameter [= value] [, ... ] ) | WITH OIDS | WITHOUT OIDS ]
[ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
[ TABLESPACE tablespace_name ]

where column_constraint is:

[ CONSTRAINT constraint_name ]
{ NOT NULL |
  NULL |
  CHECK ( expression ) [ NO INHERIT ] |
  DEFAULT default_expr |
  UNIQUE index_parameters |
  PRIMARY KEY index_parameters |
  REFERENCES reftable [ ( refcolumn ) ] [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ]
    [ ON DELETE action ] [ ON UPDATE action ] }
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and table_constraint is:

[ CONSTRAINT constraint_name ]
{ CHECK ( expression ) [ NO INHERIT ] |
  UNIQUE ( column_name [, ... ] ) index_parameters |
  PRIMARY KEY ( column_name [, ... ] ) index_parameters |
  EXCLUDE [ USING index_method ] ( exclude_element WITH operator [, ... ] ) index_parameters
  FOREIGN KEY ( column_name [, ... ] ) REFERENCES reftable [ ( refcolumn [, ... ] ) ]
    [ MATCH FULL | MATCH PARTIAL | MATCH SIMPLE ] [ ON DELETE action ] [ ON UPDATE action
[ DEFERRABLE | NOT DEFERRABLE ] [ INITIALLY DEFERRED | INITIALLY IMMEDIATE ]

and like_option is:
```

```
{ INCLUDING | EXCLUDING } { DEFAULTS | CONSTRAINTS | INDEXES | STORAGE | COMMENTS | ALL

index_parameters in UNIQUE, PRIMARY KEY, and EXCLUDE constraints are:

[ WITH ( storage_parameter [= value] [, ... ] ) ]
[ USING INDEX TABLESPACE tablespace_name ]

exclude_element in an EXCLUDE constraint is:

{ column_name | ( expression ) } [ opclass ] [ ASC | DESC ] [ NULLS { FIRST | LAST } ]
```

Description

`CREATE TABLE` will create a new, initially empty table in the current database. The table will be owned by the user issuing the command.

If a schema name is given (for example, `CREATE TABLE myschema.mytable ...`) then the table is created in the specified schema. Otherwise it is created in the current schema. Temporary tables exist in a special schema, so a schema name cannot be given when creating a temporary table. The name of the table must be distinct from the name of any other table, sequence, index, view, or foreign table in the same schema.

`CREATE TABLE` also automatically creates a data type that represents the composite type corresponding to one row of the table. Therefore, tables cannot have the same name as any existing data type in the same schema.

The optional constraint clauses specify constraints (tests) that new or updated rows must satisfy for an insert or update operation to succeed. A constraint is an SQL object that helps define the set of valid values in the table in various ways.

There are two ways to define constraints: table constraints and column constraints. A column constraint is defined as part of a column definition. A table constraint definition is not tied to a particular column, and it can encompass more than one column. Every column constraint can also be written as a table constraint; a column constraint is only a notational convenience for use when the constraint only affects one column.

To be able to create a table, you must have `USAGE` privilege on all column types or the type in the `OF` clause, respectively.

Parameters

`TEMPORARY` or `TEMP`

If specified, the table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see `ON COMMIT` below). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

The autovacuum daemon cannot access and therefore cannot vacuum or analyze temporary tables. For this reason, appropriate vacuum and analyze operations should be performed via session SQL commands. For example, if a temporary table is going to be used in complex queries, it is wise to run `ANALYZE` on the temporary table after it is populated.

Optionally, `GLOBAL` or `LOCAL` can be written before `TEMPORARY` or `TEMP`. This presently makes no difference in PostgreSQL and is deprecated; see *Compatibility*.

`UNLOGGED`

If specified, the table is created as an unlogged table. Data written to unlogged tables is not written to the write-ahead log (see Chapter 29), which makes them considerably faster than ordinary tables. However, they are not crash-safe: an unlogged table is automatically truncated after a crash or unclean shutdown. The contents of an unlogged table are also not replicated to standby servers. Any indexes created on an unlogged table are automatically unlogged as well.

`IF NOT EXISTS`

Do not throw an error if a relation with the same name already exists. A notice is issued in this case. Note that there is no guarantee that the existing relation is anything like the one that would have been created.

`table_name`

The name (optionally schema-qualified) of the table to be created.

`OF` *`type_name`*

Creates a *typed table*, which takes its structure from the specified composite type (name optionally schema-qualified). A typed table is tied to its type; for example the table will be dropped if the type is dropped (with `DROP TYPE ... CASCADE`).

When a typed table is created, then the data types of the columns are determined by the underlying composite type and are not specified by the `CREATE TABLE` command. But the `CREATE TABLE` command can add defaults and constraints to the table and can specify storage parameters.

`column_name`

The name of a column to be created in the new table.

`data_type`

The data type of the column. This can include array specifiers. For more information on the data types supported by PostgreSQL, refer to Chapter 8.

`COLLATE` *`collation`*

The `COLLATE` clause assigns a collation to the column (which must be of a collatable data type). If not specified, the column data type's default collation is used.

`INHERITS ( parent_table [, ... ] )`

The optional `INHERITS` clause specifies a list of tables from which the new table automatically inherits all columns.

Use of `INHERITS` creates a persistent relationship between the new child table and its parent table(s). Schema modifications to the parent(s) normally propagate to children as well, and by default the data of the child table is included in scans of the parent(s).

If the same column name exists in more than one parent table, an error is reported unless the data types of the columns match in each of the parent tables. If there is no conflict, then the duplicate columns are merged to form a single column in the new table. If the column name list of the new table contains a column name that is also inherited, the data type must likewise match the inherited column(s), and the column definitions are merged into one. If the new table explicitly specifies a default value for the column, this default overrides any defaults from inherited declarations of the column. Otherwise, any parents that specify default values for the column must all specify the same default, or an error will be reported.

`CHECK` constraints are merged in essentially the same way as columns: if multiple parent tables and/or the new table definition contain identically-named `CHECK` constraints, these constraints must all have the same check expression, or an error will be reported. Constraints having the same name and expression will be merged into one copy. A constraint marked `NO INHERIT` in a parent will not be considered. Notice that an unnamed `CHECK` constraint in the new table will never be merged, since a unique name will always be chosen for it.

Column `STORAGE` settings are also copied from parent tables.

`LIKE` *source_table* [*like_option* ...]

The `LIKE` clause specifies a table from which the new table automatically copies all column names, their data types, and their not-null constraints.

Unlike `INHERITS`, the new table and original table are completely decoupled after creation is complete. Changes to the original table will not be applied to the new table, and it is not possible to include data of the new table in scans of the original table.

Default expressions for the copied column definitions will only be copied if `INCLUDING DEFAULTS` is specified. Defaults that call database-modification functions, like `nextval`, create a linkage between the original and new tables. The default behavior is to exclude default expressions, resulting in the copied columns in the new table having null defaults.

Not-null constraints are always copied to the new table. `CHECK` constraints will be copied only if `INCLUDING CONSTRAINTS` is specified. Indexes, `PRIMARY KEY`, and `UNIQUE` constraints on the original table will be created on the new table only if the `INCLUDING INDEXES` clause is specified. No distinction is made between column constraints and table constraints.

`STORAGE` settings for the copied column definitions will only be copied if `INCLUDING STORAGE` is specified. The default behavior is to exclude `STORAGE` settings, resulting in the copied columns in the new table having type-specific default settings. For more on `STORAGE` settings, see Section 59.2.

Comments for the copied columns, constraints, and indexes will only be copied if `INCLUDING COMMENTS` is specified. The default behavior is to exclude comments, resulting in the copied columns and constraints in the new table having no comments.

`INCLUDING ALL` is an abbreviated form of `INCLUDING DEFAULTS INCLUDING CONSTRAINTS INCLUDING INDEXES INCLUDING STORAGE INCLUDING COMMENTS`.

Note also that unlike `INHERITS`, columns and constraints copied by `LIKE` are not merged with similarly named columns and constraints. If the same name is specified explicitly or in another `LIKE` clause, an error is signaled.

The `LIKE` clause can also be used to copy columns from views, foreign tables, or composite types. Inapplicable options (e.g., `INCLUDING INDEXES` from a view) are ignored.

`CONSTRAINT` *constraint_name*

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like `col must be positive` can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

`NOT NULL`

The column is not allowed to contain null values.

`NULL`

The column is allowed to contain null values. This is the default.

This clause is only provided for compatibility with non-standard SQL databases. Its use is discouraged in new applications.

`CHECK ( expression ) [ NO INHERIT ]`

The `CHECK` clause specifies an expression producing a Boolean result which new or updated rows must satisfy for an insert or update operation to succeed. Expressions evaluating to TRUE or UNKNOWN succeed. Should any row of an insert or update operation produce a FALSE result an error exception is raised and the insert or update does not alter the database. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint can reference multiple columns.

Currently, `CHECK` expressions cannot contain subqueries nor refer to variables other than columns of the current row. The system column `tableoid` may be referenced, but not any other system column.

A constraint marked with `NO INHERIT` will not propagate to child tables.

`DEFAULT default_expr`

The `DEFAULT` clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (subqueries and cross-references to other columns in the current table are not allowed). The data type of the default expression must match the data type of the column.

The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

`UNIQUE` (column constraint)
`UNIQUE ( column_name [, ... ] )` (table constraint)

The `UNIQUE` constraint specifies that a group of one or more columns of a table can contain only unique values. The behavior of the unique table constraint is the same as that for column constraints, with the additional capability to span multiple columns.

For the purpose of a unique constraint, null values are not considered equal.

Each unique table constraint must name a set of columns that is different from the set of columns named by any other unique or primary key constraint defined for the table. (Otherwise it would just be the same constraint listed twice.)

`PRIMARY KEY` (column constraint)
`PRIMARY KEY ( column_name [, ... ] )` (table constraint)

The primary key constraint specifies that a column or columns of a table can contain only unique (non-duplicate), nonnull values. Technically, `PRIMARY KEY` is merely a combination of `UNIQUE` and `NOT NULL`, but identifying a set of columns as primary key also provides metadata about the design of the schema, as a primary key implies that other tables can rely on this set of columns as a unique identifier for rows.

Only one primary key can be specified for a table, whether as a column constraint or a table constraint.

The primary key constraint should name a set of columns that is different from other sets of columns named by any unique constraint defined for the same table.

`EXCLUDE [ USING index_method ] ( exclude_element WITH operator [, ... ] )`
`index_parameters [ WHERE ( predicate ) ]`

The `EXCLUDE` clause defines an exclusion constraint, which guarantees that if any two rows are compared on the specified column(s) or expression(s) using the specified operator(s), not all of these comparisons will return `TRUE`. If all of the specified operators test for equality, this is

equivalent to a `UNIQUE` constraint, although an ordinary unique constraint will be faster. However, exclusion constraints can specify constraints that are more general than simple equality. For example, you can specify a constraint that no two rows in the table contain overlapping circles (see Section 8.8) by using the `&&` operator.

Exclusion constraints are implemented using an index, so each specified operator must be associated with an appropriate operator class (see Section 11.9) for the index access method *`index_method`*. The operators are required to be commutative. Each *`exclude_element`* can optionally specify an operator class and/or ordering options; these are described fully under CREATE INDEX.

The access method must support `amgettuple` (see Chapter 55); at present this means GIN cannot be used. Although it's allowed, there is little point in using B-tree or hash indexes with an exclusion constraint, because this does nothing that an ordinary unique constraint doesn't do better. So in practice the access method will always be GiST or SP-GiST.

The *`predicate`* allows you to specify an exclusion constraint on a subset of the table; internally this creates a partial index. Note that parentheses are required around the predicate.

`REFERENCES` *`reftable`* `[ ( ` *`refcolumn`* ` ) ] [ MATCH` *`matchtype`* `] [ ON DELETE` *`action`* `] [ ON UPDATE` *`action`* `]` (column constraint)
`FOREIGN KEY ( ` *`column_name`* `[, ... ] ) REFERENCES` *`reftable`* `[ ( ` *`refcolumn`* `[, ... ] ) ] [ MATCH` *`matchtype`* `] [ ON DELETE` *`action`* `] [ ON UPDATE` *`action`* `]` (table constraint)

These clauses specify a foreign key constraint, which requires that a group of one or more columns of the new table must only contain values that match values in the referenced column(s) of some row of the referenced table. If the *`refcolumn`* list is omitted, the primary key of the *`reftable`* is used. The referenced columns must be the columns of a non-deferrable unique or primary key constraint in the referenced table. Note that foreign key constraints cannot be defined between temporary tables and permanent tables.

A value inserted into the referencing column(s) is matched against the values of the referenced table and referenced columns using the given match type. There are three match types: `MATCH FULL`, `MATCH PARTIAL`, and `MATCH SIMPLE` (which is the default). `MATCH FULL` will not allow one column of a multicolumn foreign key to be null unless all foreign key columns are null; if they are all null, the row is not required to have a match in the referenced table. `MATCH SIMPLE` allows any of the foreign key columns to be null; if any of them are null, the row is not required to have a match in the referenced table. `MATCH PARTIAL` is not yet implemented. (Of course, `NOT NULL` constraints can be applied to the referencing column(s) to prevent these cases from arising.)

In addition, when the data in the referenced columns is changed, certain actions are performed on the data in this table's columns. The `ON DELETE` clause specifies the action to perform when a referenced row in the referenced table is being deleted. Likewise, the `ON UPDATE` clause specifies the action to perform when a referenced column in the referenced table is being updated to a new value. If the row is updated, but the referenced column is not actually changed, no action is done. Referential actions other than the `NO ACTION` check cannot be deferred, even if the constraint is declared deferrable. There are the following possible actions for each clause:

`NO ACTION`

Produce an error indicating that the deletion or update would create a foreign key constraint violation. If the constraint is deferred, this error will be produced at constraint check time if there still exist any referencing rows. This is the default action.

`RESTRICT`

Produce an error indicating that the deletion or update would create a foreign key constraint violation. This is the same as `NO ACTION` except that the check is not deferrable.

`CASCADE`

Delete any rows referencing the deleted row, or update the values of the referencing column(s) to the new values of the referenced columns, respectively.

`SET NULL`

Set the referencing column(s) to null.

`SET DEFAULT`

Set the referencing column(s) to their default values. (There must be a row in the referenced table matching the default values, if they are not null, or the operation will fail.)

If the referenced column(s) are changed frequently, it might be wise to add an index to the referencing column(s) so that referential actions associated with the foreign key constraint can be performed more efficiently.

`DEFERRABLE`
`NOT DEFERRABLE`

This controls whether the constraint can be deferred. A constraint that is not deferrable will be checked immediately after every command. Checking of constraints that are deferrable can be postponed until the end of the transaction (using the SET CONSTRAINTS command). `NOT DEFERRABLE` is the default. Currently, only `UNIQUE`, `PRIMARY KEY`, `EXCLUDE`, and `REFERENCES` (foreign key) constraints accept this clause. `NOT NULL` and `CHECK` constraints are not deferrable.

`INITIALLY IMMEDIATE`
`INITIALLY DEFERRED`

If a constraint is deferrable, this clause specifies the default time to check the constraint. If the constraint is `INITIALLY IMMEDIATE`, it is checked after each statement. This is the default. If the constraint is `INITIALLY DEFERRED`, it is checked only at the end of the transaction. The constraint check time can be altered with the SET CONSTRAINTS command.

`WITH ( storage_parameter [= value] [, ... ] )`

This clause specifies optional storage parameters for a table or index; see *Storage Parameters* for more information. The `WITH` clause for a table can also include `OIDS=TRUE` (or just `OIDS`) to specify that rows of the new table should have OIDs (object identifiers) assigned to them, or `OIDS=FALSE` to specify that the rows should not have OIDs. If `OIDS` is not specified, the default setting depends upon the default_with_oids configuration parameter. (If the new table inherits from any tables that have OIDs, then `OIDS=TRUE` is forced even if the command says `OIDS=FALSE`.)

If `OIDS=FALSE` is specified or implied, the new table does not store OIDs and no OID will be assigned for a row inserted into it. This is generally considered worthwhile, since it will reduce OID consumption and thereby postpone the wraparound of the 32-bit OID counter. Once the counter wraps around, OIDs can no longer be assumed to be unique, which makes them considerably less useful. In addition, excluding OIDs from a table reduces the space required to store the table on disk by 4 bytes per row (on most machines), slightly improving performance.

To remove OIDs from a table after it has been created, use ALTER TABLE.

WITH OIDS
WITHOUT OIDS

These are obsolescent syntaxes equivalent to WITH (OIDS) and WITH (OIDS=FALSE), respectively. If you wish to give both an OIDS setting and storage parameters, you must use the WITH (...) syntax; see above.

ON COMMIT

The behavior of temporary tables at the end of a transaction block can be controlled using ON COMMIT. The three options are:

PRESERVE ROWS

No special action is taken at the ends of transactions. This is the default behavior.

DELETE ROWS

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

DROP

The temporary table will be dropped at the end of the current transaction block.

TABLESPACE *tablespace_name*

The *tablespace_name* is the name of the tablespace in which the new table is to be created. If not specified, default_tablespace is consulted, or temp_tablespaces if the table is temporary.

USING INDEX TABLESPACE *tablespace_name*

This clause allows selection of the tablespace in which the index associated with a UNIQUE, PRIMARY KEY, or EXCLUDE constraint will be created. If not specified, default_tablespace is consulted, or temp_tablespaces if the table is temporary.

Storage Parameters

The WITH clause can specify *storage parameters* for tables, and for indexes associated with a UNIQUE, PRIMARY KEY, or EXCLUDE constraint. Storage parameters for indexes are documented in CREATE INDEX. The storage parameters currently available for tables are listed below. For each parameter, unless noted, there is an additional parameter with the same name prefixed with toast., which can be used to control the behavior of the table's secondary TOAST table, if any (see Section 59.2 for more information about TOAST). Note that the TOAST table inherits the autovacuum_* values from its parent table, if there are no toast.autovacuum_* settings set.

fillfactor (integer)

The fillfactor for a table is a percentage between 10 and 100. 100 (complete packing) is the default. When a smaller fillfactor is specified, INSERT operations pack table pages only to the indicated percentage; the remaining space on each page is reserved for updating rows on that page. This gives UPDATE a chance to place the updated copy of a row on the same page as the original, which is more efficient than placing it on a different page. For a table whose entries are never updated, complete packing is the best choice, but in heavily updated tables smaller fillfactors are appropriate. This parameter cannot be set for TOAST tables.

autovacuum_enabled, toast.autovacuum_enabled (boolean)

Enables or disables the autovacuum daemon on a particular table. If true, the autovacuum daemon will initiate a VACUUM operation on a particular table when the number of updated or deleted tu-

ples exceeds `autovacuum_vacuum_threshold` plus `autovacuum_vacuum_scale_factor` times the number of live tuples currently estimated to be in the relation. Similarly, it will initiate an `ANALYZE` operation when the number of inserted, updated or deleted tuples exceeds `autovacuum_analyze_threshold` plus `autovacuum_analyze_scale_factor` times the number of live tuples currently estimated to be in the relation. If false, this table will not be autovacuumed, except to prevent transaction Id wraparound. See Section 23.1.5 for more about wraparound prevention. Observe that this variable inherits its value from the autovacuum setting.

`autovacuum_vacuum_threshold`, `toast.autovacuum_vacuum_threshold` (`integer`)

Minimum number of updated or deleted tuples before initiate a `VACUUM` operation on a particular table.

`autovacuum_vacuum_scale_factor`, `toast.autovacuum_vacuum_scale_factor` (`float4`)

Multiplier for `reltuples` to add to `autovacuum_vacuum_threshold`.

`autovacuum_analyze_threshold` (`integer`)

Minimum number of inserted, updated, or deleted tuples before initiate an `ANALYZE` operation on a particular table.

`autovacuum_analyze_scale_factor` (`float4`)

Multiplier for `reltuples` to add to `autovacuum_analyze_threshold`.

`autovacuum_vacuum_cost_delay`, `toast.autovacuum_vacuum_cost_delay` (`integer`)

Custom autovacuum_vacuum_cost_delay parameter.

`autovacuum_vacuum_cost_limit`, `toast.autovacuum_vacuum_cost_limit` (`integer`)

Custom autovacuum_vacuum_cost_limit parameter.

`autovacuum_freeze_min_age`, `toast.autovacuum_freeze_min_age` (`integer`)

Custom vacuum_freeze_min_age parameter. Note that autovacuum will ignore attempts to set a per-table `autovacuum_freeze_min_age` larger than half the system-wide autovacuum_freeze_max_age setting.

`autovacuum_freeze_max_age`, `toast.autovacuum_freeze_max_age` (`integer`)

Custom autovacuum_freeze_max_age parameter. Note that autovacuum will ignore attempts to set a per-table `autovacuum_freeze_max_age` larger than the system-wide setting (it can only be set smaller). Note that while you can set `autovacuum_freeze_max_age` very small, or even zero, this is usually unwise since it will force frequent vacuuming.

`autovacuum_freeze_table_age`, `toast.autovacuum_freeze_table_age` (`integer`)

Custom vacuum_freeze_table_age parameter.

`autovacuum_multixact_freeze_min_age`, `toast.autovacuum_multixact_freeze_min_age` (`integer`)

Custom vacuum_multixact_freeze_min_age parameter. Note that autovacuum will ignore attempts to set a per-table `autovacuum_multixact_freeze_min_age` larger than half the system-wide autovacuum_multixact_freeze_max_age setting.

`autovacuum_multixact_freeze_max_age`, `toast.autovacuum_multixact_freeze_max_age` (`integer`)

Custom autovacuum_multixact_freeze_max_age parameter. Note that autovacuum will ignore attempts to set a per-table `autovacuum_multixact_freeze_max_age` larger than the system-wide setting (it can only be set smaller). Note that while you can set

autovacuum_multixact_freeze_max_age very small, or even zero, this is usually unwise since it will force frequent vacuuming.

autovacuum_multixact_freeze_table_age, toast.autovacuum_multixact_freeze_table_age (integer)

Custom vacuum_multixact_freeze_table_age parameter.

user_catalog_table (boolean)

Declare a table as an additional catalog table, e.g. for the purpose of logical replication. See Section 46.6.2 for details.

Notes

Using OIDs in new applications is not recommended: where possible, using a SERIAL or other sequence generator as the table's primary key is preferred. However, if your application does make use of OIDs to identify specific rows of a table, it is recommended to create a unique constraint on the oid column of that table, to ensure that OIDs in the table will indeed uniquely identify rows even after counter wraparound. Avoid assuming that OIDs are unique across tables; if you need a database-wide unique identifier, use the combination of tableoid and row OID for the purpose.

Tip: The use of OIDS=FALSE is not recommended for tables with no primary key, since without either an OID or a unique data key, it is difficult to identify specific rows.

PostgreSQL automatically creates an index for each unique constraint and primary key constraint to enforce uniqueness. Thus, it is not necessary to create an index explicitly for primary key columns. (See CREATE INDEX for more information.)

Unique constraints and primary keys are not inherited in the current implementation. This makes the combination of inheritance and unique constraints rather dysfunctional.

A table cannot have more than 1600 columns. (In practice, the effective limit is usually lower because of tuple-length constraints.)

Examples

Create table films and table distributors:

```
CREATE TABLE films (
    code        char(5) CONSTRAINT firstkey PRIMARY KEY,
    title       varchar(40) NOT NULL,
    did         integer NOT NULL,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute
);

CREATE TABLE distributors (
     did    integer PRIMARY KEY DEFAULT nextval('serial'),
     name   varchar(40) NOT NULL CHECK (name <> '')
);
```

Create a table with a 2-dimensional array:

```
CREATE TABLE array_int (
    vector  int[][]
);
```

Define a unique table constraint for the table `films`. Unique table constraints can be defined on one or more columns of the table:

```
CREATE TABLE films (
    code        char(5),
    title       varchar(40),
    did         integer,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute,
    CONSTRAINT production UNIQUE(date_prod)
);
```

Define a check column constraint:

```
CREATE TABLE distributors (
    did     integer CHECK (did > 100),
    name    varchar(40)
);
```

Define a check table constraint:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40)
    CONSTRAINT con1 CHECK (did > 100 AND name <> '')
);
```

Define a primary key table constraint for the table `films`:

```
CREATE TABLE films (
    code        char(5),
    title       varchar(40),
    did         integer,
    date_prod   date,
    kind        varchar(10),
    len         interval hour to minute,
    CONSTRAINT code_title PRIMARY KEY(code,title)
);
```

Define a primary key constraint for table `distributors`. The following two examples are equivalent, the first using the table constraint syntax, the second the column constraint syntax:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    PRIMARY KEY(did)
);

CREATE TABLE distributors (
    did     integer PRIMARY KEY,
    name    varchar(40)
);
```

Assign a literal constant default value for the column `name`, arrange for the default value of column `did` to be generated by selecting the next value of a sequence object, and make the default value of `modtime` be the time at which the row is inserted:

```
CREATE TABLE distributors (
    name      varchar(40) DEFAULT 'Luso Films',
    did       integer DEFAULT nextval('distributors_serial'),
    modtime   timestamp DEFAULT current_timestamp
);
```

Define two `NOT NULL` column constraints on the table `distributors`, one of which is explicitly given a name:

```
CREATE TABLE distributors (
    did     integer CONSTRAINT no_null NOT NULL,
    name    varchar(40) NOT NULL
);
```

Define a unique constraint for the `name` column:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40) UNIQUE
);
```

The same, specified as a table constraint:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    UNIQUE(name)
);
```

Create the same table, specifying 70% fill factor for both the table and its unique index:

```
CREATE TABLE distributors (
    did     integer,
    name    varchar(40),
    UNIQUE(name) WITH (fillfactor=70)
)
WITH (fillfactor=70);
```

Create table `circles` with an exclusion constraint that prevents any two circles from overlapping:

```
CREATE TABLE circles (
    c circle,
    EXCLUDE USING gist (c WITH &&)
);
```

Create table `cinemas` in tablespace `diskvol1`:

```
CREATE TABLE cinemas (
        id serial,
        name text,
        location text
) TABLESPACE diskvol1;
```

Create a composite type and a typed table:

```
CREATE TYPE employee_type AS (name text, salary numeric);

CREATE TABLE employees OF employee_type (
    PRIMARY KEY (name),
    salary WITH OPTIONS DEFAULT 1000
);
```

Compatibility

The `CREATE TABLE` command conforms to the SQL standard, with exceptions listed below.

Temporary Tables

Although the syntax of `CREATE TEMPORARY TABLE` resembles that of the SQL standard, the effect is not the same. In the standard, temporary tables are defined just once and automatically exist (starting with empty contents) in every session that needs them. PostgreSQL instead requires each session to issue its own `CREATE TEMPORARY TABLE` command for each temporary table to be used. This allows different sessions to use the same temporary table name for different purposes, whereas the standard's approach constrains all instances of a given temporary table name to have the same table structure.

The standard's definition of the behavior of temporary tables is widely ignored. PostgreSQL's behavior on this point is similar to that of several other SQL databases.

The SQL standard also distinguishes between global and local temporary tables, where a local temporary table has a separate set of contents for each SQL module within each session, though its definition is still shared across sessions. Since PostgreSQL does not support SQL modules, this distinction is not relevant in PostgreSQL.

For compatibility's sake, PostgreSQL will accept the `GLOBAL` and `LOCAL` keywords in a temporary table declaration, but they currently have no effect. Use of these keywords is discouraged, since future versions of PostgreSQL might adopt a more standard-compliant interpretation of their meaning.

The `ON COMMIT` clause for temporary tables also resembles the SQL standard, but has some differences. If the `ON COMMIT` clause is omitted, SQL specifies that the default behavior is `ON COMMIT DELETE ROWS`. However, the default behavior in PostgreSQL is `ON COMMIT PRESERVE ROWS`. The `ON COMMIT DROP` option does not exist in SQL.

Non-deferred Uniqueness Constraints

When a `UNIQUE` or `PRIMARY KEY` constraint is not deferrable, PostgreSQL checks for uniqueness immediately whenever a row is inserted or modified. The SQL standard says that uniqueness should be enforced only at the end of the statement; this makes a difference when, for example, a single command updates multiple key values. To obtain standard-compliant behavior, declare the constraint as `DEFERRABLE` but not deferred (i.e., `INITIALLY IMMEDIATE`). Be aware that this can be significantly slower than immediate uniqueness checking.

Column Check Constraints

The SQL standard says that `CHECK` column constraints can only refer to the column they apply to; only `CHECK` table constraints can refer to multiple columns. PostgreSQL does not enforce this restriction; it treats column and table check constraints alike.

`EXCLUDE` Constraint

The `EXCLUDE` constraint type is a PostgreSQL extension.

`NULL` "Constraint"

The `NULL` "constraint" (actually a non-constraint) is a PostgreSQL extension to the SQL standard that is included for compatibility with some other database systems (and for symmetry with the `NOT NULL` constraint). Since it is the default for any column, its presence is simply noise.

Inheritance

Multiple inheritance via the `INHERITS` clause is a PostgreSQL language extension. SQL:1999 and later define single inheritance using a different syntax and different semantics. SQL:1999-style inheritance is not yet supported by PostgreSQL.

Zero-column Tables

PostgreSQL allows a table of no columns to be created (for example, `CREATE TABLE foo();`). This is an extension from the SQL standard, which does not allow zero-column tables. Zero-column tables are not in themselves very useful, but disallowing them creates odd special cases for `ALTER TABLE DROP COLUMN`, so it seems cleaner to ignore this spec restriction.

`WITH` Clause

The `WITH` clause is a PostgreSQL extension; neither storage parameters nor OIDs are in the standard.

Tablespaces

The PostgreSQL concept of tablespaces is not part of the standard. Hence, the clauses `TABLESPACE` and `USING INDEX TABLESPACE` are extensions.

Typed Tables

Typed tables implement a subset of the SQL standard. According to the standard, a typed table has columns corresponding to the underlying composite type as well as one other column that is the "self-referencing column". PostgreSQL does not support these self-referencing columns explicitly, but the same effect can be had using the OID feature.

See Also

ALTER TABLE, DROP TABLE, CREATE TABLE AS, CREATE TABLESPACE, CREATE TYPE

CREATE TABLE AS

Name

CREATE TABLE AS — define a new table from the results of a query

Synopsis

```
CREATE [ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE table_name
    [ (column_name [, ...] ) ]
    [ WITH ( storage_parameter [= value] [, ... ] ) | WITH OIDS | WITHOUT OIDS ]
    [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
    [ TABLESPACE tablespace_name ]
    AS query
    [ WITH [ NO ] DATA ]
```

Description

CREATE TABLE AS creates a table and fills it with data computed by a SELECT command. The table columns have the names and data types associated with the output columns of the SELECT (except that you can override the column names by giving an explicit list of new column names).

CREATE TABLE AS bears some resemblance to creating a view, but it is really quite different: it creates a new table and evaluates the query just once to fill the new table initially. The new table will not track subsequent changes to the source tables of the query. In contrast, a view re-evaluates its defining SELECT statement whenever it is queried.

Parameters

GLOBAL or LOCAL

Ignored for compatibility. Use of these keywords is deprecated; refer to CREATE TABLE for details.

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

table_name

The name (optionally schema-qualified) of the table to be created.

column_name

The name of a column in the new table. If column names are not provided, they are taken from the output column names of the query.

`WITH ( storage_parameter [= value] [, ... ] )`

This clause specifies optional storage parameters for the new table; see *Storage Parameters* for more information. The `WITH` clause can also include `OIDS=TRUE` (or just `OIDS`) to specify that rows of the new table should have OIDs (object identifiers) assigned to them, or `OIDS=FALSE` to specify that the rows should not have OIDs. See CREATE TABLE for more information.

`WITH OIDS`
`WITHOUT OIDS`

These are obsolescent syntaxes equivalent to `WITH (OIDS)` and `WITH (OIDS=FALSE)`, respectively. If you wish to give both an `OIDS` setting and storage parameters, you must use the `WITH ( ... )` syntax; see above.

`ON COMMIT`

The behavior of temporary tables at the end of a transaction block can be controlled using `ON COMMIT`. The three options are:

`PRESERVE ROWS`

No special action is taken at the ends of transactions. This is the default behavior.

`DELETE ROWS`

All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

`DROP`

The temporary table will be dropped at the end of the current transaction block.

`TABLESPACE tablespace_name`

The *`tablespace_name`* is the name of the tablespace in which the new table is to be created. If not specified, default_tablespace is consulted, or temp_tablespaces if the table is temporary.

`query`

A SELECT, TABLE, or VALUES command, or an EXECUTE command that runs a prepared `SELECT`, `TABLE`, or `VALUES` query.

`WITH [ NO ] DATA`

This clause specifies whether or not the data produced by the query should be copied into the new table. If not, only the table structure is copied. The default is to copy the data.

Notes

This command is functionally similar to SELECT INTO, but it is preferred since it is less likely to be confused with other uses of the `SELECT INTO` syntax. Furthermore, `CREATE TABLE AS` offers a superset of the functionality offered by `SELECT INTO`.

The `CREATE TABLE AS` command allows the user to explicitly specify whether OIDs should be included. If the presence of OIDs is not explicitly specified, the default_with_oids configuration variable is used.

Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
CREATE TABLE films_recent AS
  SELECT * FROM films WHERE date_prod >= '2002-01-01';
```

To copy a table completely, the short form using the `TABLE` command can also be used:

```
CREATE TABLE films2 AS
  TABLE films;
```

Create a new temporary table `films_recent`, consisting of only recent entries from the table `films`, using a prepared statement. The new table has OIDs and will be dropped at commit:

```
PREPARE recentfilms(date) AS
  SELECT * FROM films WHERE date_prod > $1;
CREATE TEMP TABLE films_recent WITH (OIDS) ON COMMIT DROP AS
  EXECUTE recentfilms('2002-01-01');
```

Compatibility

`CREATE TABLE AS` conforms to the SQL standard. The following are nonstandard extensions:

- The standard requires parentheses around the subquery clause; in PostgreSQL, these parentheses are optional.
- In the standard, the `WITH [ NO ] DATA` clause is required; in PostgreSQL it is optional.
- PostgreSQL handles temporary tables in a way rather different from the standard; see CREATE TABLE for details.
- The `WITH` clause is a PostgreSQL extension; neither storage parameters nor OIDs are in the standard.
- The PostgreSQL concept of tablespaces is not part of the standard. Hence, the clause `TABLESPACE` is an extension.

See Also

CREATE MATERIALIZED VIEW, CREATE TABLE, EXECUTE, SELECT, SELECT INTO, VALUES

CREATE TABLESPACE

Name

CREATE TABLESPACE — define a new tablespace

Synopsis

```
CREATE TABLESPACE tablespace_name
    [ OWNER user_name ]
    LOCATION 'directory'
    [ WITH ( tablespace_option = value [, ... ] ) ]
```

Description

CREATE TABLESPACE registers a new cluster-wide tablespace. The tablespace name must be distinct from the name of any existing tablespace in the database cluster.

A tablespace allows superusers to define an alternative location on the file system where the data files containing database objects (such as tables and indexes) can reside.

A user with appropriate privileges can pass *tablespace_name* to CREATE DATABASE, CREATE TABLE, CREATE INDEX or ADD CONSTRAINT to have the data files for these objects stored within the specified tablespace.

Warning

A tablespace cannot be used independently of the cluster in which it is defined; see Section 21.6>.

Parameters

tablespace_name

The name of a tablespace to be created. The name cannot begin with pg_, as such names are reserved for system tablespaces.

user_name

The name of the user who will own the tablespace. If omitted, defaults to the user executing the command. Only superusers can create tablespaces, but they can assign ownership of tablespaces to non-superusers.

directory

The directory that will be used for the tablespace. The directory should be empty and must be owned by the PostgreSQL system user. The directory must be specified by an absolute path name.

tablespace_option

A tablespace parameter to be set or reset. Currently, the only available parameters are `seq_page_cost` and `random_page_cost`. Setting either value for a particular tablespace will override the planner's usual estimate of the cost of reading pages from tables in that tablespace, as established by the configuration parameters of the same name (see seq_page_cost, random_page_cost). This may be useful if one tablespace is located on a disk which is faster or slower than the remainder of the I/O subsystem.

Notes

Tablespaces are only supported on systems that support symbolic links.

`CREATE TABLESPACE` cannot be executed inside a transaction block.

Examples

Create a tablespace `dbspace` at `/data/dbs`:

```
CREATE TABLESPACE dbspace LOCATION '/data/dbs';
```

Create a tablespace `indexspace` at `/data/indexes` owned by user `genevieve`:

```
CREATE TABLESPACE indexspace OWNER genevieve LOCATION '/data/indexes';
```

Compatibility

`CREATE TABLESPACE` is a PostgreSQL extension.

See Also

CREATE DATABASE, CREATE TABLE, CREATE INDEX, DROP TABLESPACE, ALTER TABLESPACE

CREATE TEXT SEARCH CONFIGURATION

Name

CREATE TEXT SEARCH CONFIGURATION — define a new text search configuration

Synopsis

```
CREATE TEXT SEARCH CONFIGURATION name (
    PARSER = parser_name |
    COPY = source_config
)
```

Description

CREATE TEXT SEARCH CONFIGURATION creates a new text search configuration. A text search configuration specifies a text search parser that can divide a string into tokens, plus dictionaries that can be used to determine which tokens are of interest for searching.

If only the parser is specified, then the new text search configuration initially has no mappings from token types to dictionaries, and therefore will ignore all words. Subsequent ALTER TEXT SEARCH CONFIGURATION commands must be used to create mappings to make the configuration useful. Alternatively, an existing text search configuration can be copied.

If a schema name is given then the text search configuration is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search configuration becomes its owner.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search configuration to be created. The name can be schema-qualified.

parser_name

The name of the text search parser to use for this configuration.

source_config

The name of an existing text search configuration to copy.

Notes

The PARSER and COPY options are mutually exclusive, because when an existing configuration is copied, its parser selection is copied too.

Compatibility

There is no `CREATE TEXT SEARCH CONFIGURATION` statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, DROP TEXT SEARCH CONFIGURATION

CREATE TEXT SEARCH DICTIONARY

Name

CREATE TEXT SEARCH DICTIONARY — define a new text search dictionary

Synopsis

```
CREATE TEXT SEARCH DICTIONARY name (
    TEMPLATE = template
    [, option = value [, ... ]]
)
```

Description

CREATE TEXT SEARCH DICTIONARY creates a new text search dictionary. A text search dictionary specifies a way of recognizing interesting or uninteresting words for searching. A dictionary depends on a text search template, which specifies the functions that actually perform the work. Typically the dictionary provides some options that control the detailed behavior of the template's functions.

If a schema name is given then the text search dictionary is created in the specified schema. Otherwise it is created in the current schema.

The user who defines a text search dictionary becomes its owner.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search dictionary to be created. The name can be schema-qualified.

template

The name of the text search template that will define the basic behavior of this dictionary.

option

The name of a template-specific option to be set for this dictionary.

value

The value to use for a template-specific option. If the value is not a simple identifier or number, it must be quoted (but you can always quote it, if you wish).

The options can appear in any order.

Examples

The following example command creates a Snowball-based dictionary with a nonstandard list of stop words.

```
CREATE TEXT SEARCH DICTIONARY my_russian (
```

```
    template = snowball,
    language = russian,
    stopwords = myrussian
);
```

Compatibility

There is no `CREATE TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

ALTER TEXT SEARCH DICTIONARY, DROP TEXT SEARCH DICTIONARY

CREATE TEXT SEARCH PARSER

Name

CREATE TEXT SEARCH PARSER — define a new text search parser

Synopsis

```
CREATE TEXT SEARCH PARSER name (
    START = start_function ,
    GETTOKEN = gettoken_function ,
    END = end_function ,
    LEXTYPES = lextypes_function
    [, HEADLINE = headline_function ]
)
```

Description

CREATE TEXT SEARCH PARSER creates a new text search parser. A text search parser defines a method for splitting a text string into tokens and assigning types (categories) to the tokens. A parser is not particularly useful by itself, but must be bound into a text search configuration along with some text search dictionaries to be used for searching.

If a schema name is given then the text search parser is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH PARSER. (This restriction is made because an erroneous text search parser definition could confuse or even crash the server.)

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search parser to be created. The name can be schema-qualified.

start_function

The name of the start function for the parser.

gettoken_function

The name of the get-next-token function for the parser.

end_function

The name of the end function for the parser.

lextypes_function

The name of the lextypes function for the parser (a function that returns information about the set of token types it produces).

headline_function

The name of the headline function for the parser (a function that summarizes a set of tokens).

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. All except the headline function are required.

The arguments can appear in any order, not only the one shown above.

Compatibility

There is no `CREATE TEXT SEARCH PARSER` statement in the SQL standard.

See Also

ALTER TEXT SEARCH PARSER, DROP TEXT SEARCH PARSER

CREATE TEXT SEARCH TEMPLATE

Name

CREATE TEXT SEARCH TEMPLATE — define a new text search template

Synopsis

```
CREATE TEXT SEARCH TEMPLATE name (
    [ INIT = init_function , ]
    LEXIZE = lexize_function
)
```

Description

CREATE TEXT SEARCH TEMPLATE creates a new text search template. Text search templates define the functions that implement text search dictionaries. A template is not useful by itself, but must be instantiated as a dictionary to be used. The dictionary typically specifies parameters to be given to the template functions.

If a schema name is given then the text search template is created in the specified schema. Otherwise it is created in the current schema.

You must be a superuser to use CREATE TEXT SEARCH TEMPLATE. This restriction is made because an erroneous text search template definition could confuse or even crash the server. The reason for separating templates from dictionaries is that a template encapsulates the "unsafe" aspects of defining a dictionary. The parameters that can be set when defining a dictionary are safe for unprivileged users to set, and so creating a dictionary need not be a privileged operation.

Refer to Chapter 12 for further information.

Parameters

name

The name of the text search template to be created. The name can be schema-qualified.

init_function

The name of the init function for the template.

lexize_function

The name of the lexize function for the template.

The function names can be schema-qualified if necessary. Argument types are not given, since the argument list for each type of function is predetermined. The lexize function is required, but the init function is optional.

The arguments can appear in any order, not only the one shown above.

Compatibility

There is no `CREATE TEXT SEARCH TEMPLATE` statement in the SQL standard.

See Also

ALTER TEXT SEARCH TEMPLATE, DROP TEXT SEARCH TEMPLATE

CREATE TRIGGER

Name

CREATE TRIGGER — define a new trigger

Synopsis

```
CREATE [ CONSTRAINT ] TRIGGER name { BEFORE | AFTER | INSTEAD OF } { event [ OR ... ] }
    ON table_name
    [ FROM referenced_table_name ]
    [ NOT DEFERRABLE | [ DEFERRABLE ] { INITIALLY IMMEDIATE | INITIALLY DEFERRED } ]
    [ FOR [ EACH ] { ROW | STATEMENT } ]
    [ WHEN ( condition ) ]
    EXECUTE PROCEDURE function_name ( arguments )

where event can be one of:

    INSERT
    UPDATE [ OF column_name [, ... ] ]
    DELETE
    TRUNCATE
```

Description

CREATE TRIGGER creates a new trigger. The trigger will be associated with the specified table, view, or foreign table and will execute the specified function *function_name* when certain events occur.

The trigger can be specified to fire before the operation is attempted on a row (before constraints are checked and the INSERT, UPDATE, or DELETE is attempted); or after the operation has completed (after constraints are checked and the INSERT, UPDATE, or DELETE has completed); or instead of the operation (in the case of inserts, updates or deletes on a view). If the trigger fires before or instead of the event, the trigger can skip the operation for the current row, or change the row being inserted (for INSERT and UPDATE operations only). If the trigger fires after the event, all changes, including the effects of other triggers, are "visible" to the trigger.

A trigger that is marked FOR EACH ROW is called once for every row that the operation modifies. For example, a DELETE that affects 10 rows will cause any ON DELETE triggers on the target relation to be called 10 separate times, once for each deleted row. In contrast, a trigger that is marked FOR EACH STATEMENT only executes once for any given operation, regardless of how many rows it modifies (in particular, an operation that modifies zero rows will still result in the execution of any applicable FOR EACH STATEMENT triggers).

Triggers that are specified to fire INSTEAD OF the trigger event must be marked FOR EACH ROW, and can only be defined on views. BEFORE and AFTER triggers on a view must be marked as FOR EACH STATEMENT.

In addition, triggers may be defined to fire for TRUNCATE, though only FOR EACH STATEMENT.

The following table summarizes which types of triggers may be used on tables, views, and foreign tables:

When	Event	Row-level	Statement-level

When	Event	Row-level	Statement-level
BEFORE	INSERT/UPDATE/DELETE	Tables and foreign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
AFTER	INSERT/UPDATE/DELETE	Tables and foreign tables	Tables, views, and foreign tables
	TRUNCATE	—	Tables
INSTEAD OF	INSERT/UPDATE/DELETE	Views	—
	TRUNCATE	—	—

Also, a trigger definition can specify a Boolean WHEN condition, which will be tested to see whether the trigger should be fired. In row-level triggers the WHEN condition can examine the old and/or new values of columns of the row. Statement-level triggers can also have WHEN conditions, although the feature is not so useful for them since the condition cannot refer to any values in the table.

If multiple triggers of the same kind are defined for the same event, they will be fired in alphabetical order by name.

When the CONSTRAINT option is specified, this command creates a *constraint trigger*. This is the same as a regular trigger except that the timing of the trigger firing can be adjusted using SET CONSTRAINTS. Constraint triggers must be AFTER ROW triggers on tables. They can be fired either at the end of the statement causing the triggering event, or at the end of the containing transaction; in the latter case they are said to be *deferred*. A pending deferred-trigger firing can also be forced to happen immediately by using SET CONSTRAINTS. Constraint triggers are expected to raise an exception when the constraints they implement are violated.

SELECT does not modify any rows so you cannot create SELECT triggers. Rules and views are more appropriate in such cases.

Refer to Chapter 36 for more information about triggers.

Parameters

name

The name to give the new trigger. This must be distinct from the name of any other trigger for the same table. The name cannot be schema-qualified — the trigger inherits the schema of its table. For a constraint trigger, this is also the name to use when modifying the trigger's behavior using SET CONSTRAINTS.

BEFORE
AFTER
INSTEAD OF

Determines whether the function is called before, after, or instead of the event. A constraint trigger can only be specified as AFTER.

event

One of INSERT, UPDATE, DELETE, or TRUNCATE; this specifies the event that will fire the trigger. Multiple events can be specified using OR.

For `UPDATE` events, it is possible to specify a list of columns using this syntax:

`UPDATE OF` *`column_name1`* `[,` *`column_name2`* `... ]`

The trigger will only fire if at least one of the listed columns is mentioned as a target of the `UPDATE` command.

`INSTEAD OF UPDATE` events do not support lists of columns.

`table_name`

The name (optionally schema-qualified) of the table, view, or foreign table the trigger is for.

`referenced_table_name`

The (possibly schema-qualified) name of another table referenced by the constraint. This option is used for foreign-key constraints and is not recommended for general use. This can only be specified for constraint triggers.

`DEFERRABLE`
`NOT DEFERRABLE`
`INITIALLY IMMEDIATE`
`INITIALLY DEFERRED`

The default timing of the trigger. See the CREATE TABLE documentation for details of these constraint options. This can only be specified for constraint triggers.

`FOR EACH ROW`
`FOR EACH STATEMENT`

This specifies whether the trigger procedure should be fired once for every row affected by the trigger event, or just once per SQL statement. If neither is specified, `FOR EACH STATEMENT` is the default. Constraint triggers can only be specified `FOR EACH ROW`.

`condition`

A Boolean expression that determines whether the trigger function will actually be executed. If `WHEN` is specified, the function will only be called if the *`condition`* returns `true`. In `FOR EACH ROW` triggers, the `WHEN` condition can refer to columns of the old and/or new row values by writing `OLD.`*`column_name`* or `NEW.`*`column_name`* respectively. Of course, `INSERT` triggers cannot refer to `OLD` and `DELETE` triggers cannot refer to `NEW`.

`INSTEAD OF` triggers do not support `WHEN` conditions.

Currently, `WHEN` expressions cannot contain subqueries.

Note that for constraint triggers, evaluation of the `WHEN` condition is not deferred, but occurs immediately after the row update operation is performed. If the condition does not evaluate to true then the trigger is not queued for deferred execution.

`function_name`

A user-supplied function that is declared as taking no arguments and returning type `trigger`, which is executed when the trigger fires.

`arguments`

An optional comma-separated list of arguments to be provided to the function when the trigger is executed. The arguments are literal string constants. Simple names and numeric constants can be written here, too, but they will all be converted to strings. Please check the description of the implementation language of the trigger function to find out how these arguments can be accessed within the function; it might be different from normal function arguments.

Notes

To create a trigger on a table, the user must have the TRIGGER privilege on the table. The user must also have EXECUTE privilege on the trigger function.

Use DROP TRIGGER to remove a trigger.

A column-specific trigger (one defined using the UPDATE OF *column_name* syntax) will fire when any of its columns are listed as targets in the UPDATE command's SET list. It is possible for a column's value to change even when the trigger is not fired, because changes made to the row's contents by BEFORE UPDATE triggers are not considered. Conversely, a command such as UPDATE ... SET x = x ... will fire a trigger on column x, even though the column's value did not change.

In a BEFORE trigger, the WHEN condition is evaluated just before the function is or would be executed, so using WHEN is not materially different from testing the same condition at the beginning of the trigger function. Note in particular that the NEW row seen by the condition is the current value, as possibly modified by earlier triggers. Also, a BEFORE trigger's WHEN condition is not allowed to examine the system columns of the NEW row (such as oid), because those won't have been set yet.

In an AFTER trigger, the WHEN condition is evaluated just after the row update occurs, and it determines whether an event is queued to fire the trigger at the end of statement. So when an AFTER trigger's WHEN condition does not return true, it is not necessary to queue an event nor to re-fetch the row at end of statement. This can result in significant speedups in statements that modify many rows, if the trigger only needs to be fired for a few of the rows.

In PostgreSQL versions before 7.3, it was necessary to declare trigger functions as returning the placeholder type opaque, rather than trigger. To support loading of old dump files, CREATE TRIGGER will accept a function declared as returning opaque, but it will issue a notice and change the function's declared return type to trigger.

Examples

Execute the function check_account_update whenever a row of the table accounts is about to be updated:

```
CREATE TRIGGER check_update
    BEFORE UPDATE ON accounts
    FOR EACH ROW
    EXECUTE PROCEDURE check_account_update();
```

The same, but only execute the function if column balance is specified as a target in the UPDATE command:

```
CREATE TRIGGER check_update
    BEFORE UPDATE OF balance ON accounts
    FOR EACH ROW
    EXECUTE PROCEDURE check_account_update();
```

This form only executes the function if column balance has in fact changed value:

```
CREATE TRIGGER check_update
    BEFORE UPDATE ON accounts
    FOR EACH ROW
    WHEN (OLD.balance IS DISTINCT FROM NEW.balance)
    EXECUTE PROCEDURE check_account_update();
```

Call a function to log updates of accounts, but only if something changed:

```
CREATE TRIGGER log_update
    AFTER UPDATE ON accounts
    FOR EACH ROW
    WHEN (OLD.* IS DISTINCT FROM NEW.*)
    EXECUTE PROCEDURE log_account_update();
```

Execute the function `view_insert_row` for each row to insert rows into the tables underlying a view:

```
CREATE TRIGGER view_insert
    INSTEAD OF INSERT ON my_view
    FOR EACH ROW
    EXECUTE PROCEDURE view_insert_row();
```

Section 36.4 contains a complete example of a trigger function written in C.

Compatibility

The `CREATE TRIGGER` statement in PostgreSQL implements a subset of the SQL standard. The following functionalities are currently missing:

- SQL allows you to define aliases for the "old" and "new" rows or tables for use in the definition of the triggered action (e.g., `CREATE TRIGGER ... ON tablename REFERENCING OLD ROW AS somename NEW ROW AS othername ...`). Since PostgreSQL allows trigger procedures to be written in any number of user-defined languages, access to the data is handled in a language-specific way.
- PostgreSQL does not allow the old and new tables to be referenced in statement-level triggers, i.e., the tables that contain all the old and/or new rows, which are referred to by the `OLD TABLE` and `NEW TABLE` clauses in the SQL standard.
- PostgreSQL only allows the execution of a user-defined function for the triggered action. The standard allows the execution of a number of other SQL commands, such as `CREATE TABLE`, as the triggered action. This limitation is not hard to work around by creating a user-defined function that executes the desired commands.

SQL specifies that multiple triggers should be fired in time-of-creation order. PostgreSQL uses name order, which was judged to be more convenient.

SQL specifies that `BEFORE DELETE` triggers on cascaded deletes fire *after* the cascaded `DELETE` completes. The PostgreSQL behavior is for `BEFORE DELETE` to always fire before the delete action, even a cascading one. This is considered more consistent. There is also nonstandard behavior if `BEFORE` triggers modify rows or prevent updates during an update that is caused by a referential action. This can lead to constraint violations or stored data that does not honor the referential constraint.

The ability to specify multiple actions for a single trigger using `OR` is a PostgreSQL extension of the SQL standard.

The ability to fire triggers for `TRUNCATE` is a PostgreSQL extension of the SQL standard, as is the ability to define statement-level triggers on views.

`CREATE CONSTRAINT TRIGGER` is a PostgreSQL extension of the SQL standard.

See Also

ALTER TRIGGER, DROP TRIGGER, CREATE FUNCTION, SET CONSTRAINTS

CREATE TYPE

Name

CREATE TYPE — define a new data type

Synopsis

```
CREATE TYPE name AS
    ( [ attribute_name data_type [ COLLATE collation ] [, ... ] ] )

CREATE TYPE name AS ENUM
    ( [ 'label' [, ... ] ] )

CREATE TYPE name AS RANGE (
    SUBTYPE = subtype
    [ , SUBTYPE_OPCLASS = subtype_operator_class ]
    [ , COLLATION = collation ]
    [ , CANONICAL = canonical_function ]
    [ , SUBTYPE_DIFF = subtype_diff_function ]
)

CREATE TYPE name (
    INPUT = input_function,
    OUTPUT = output_function
    [ , RECEIVE = receive_function ]
    [ , SEND = send_function ]
    [ , TYPMOD_IN = type_modifier_input_function ]
    [ , TYPMOD_OUT = type_modifier_output_function ]
    [ , ANALYZE = analyze_function ]
    [ , INTERNALLENGTH = { internallength | VARIABLE } ]
    [ , PASSEDBYVALUE ]
    [ , ALIGNMENT = alignment ]
    [ , STORAGE = storage ]
    [ , LIKE = like_type ]
    [ , CATEGORY = category ]
    [ , PREFERRED = preferred ]
    [ , DEFAULT = default ]
    [ , ELEMENT = element ]
    [ , DELIMITER = delimiter ]
    [ , COLLATABLE = collatable ]
)

CREATE TYPE name
```

Description

CREATE TYPE registers a new data type for use in the current database. The user who defines a type becomes its owner.

If a schema name is given then the type is created in the specified schema. Otherwise it is created in the current schema. The type name must be distinct from the name of any existing type or domain

in the same schema. (Because tables have associated data types, the type name must also be distinct from the name of any existing table in the same schema.)

There are five forms of CREATE TYPE, as shown in the syntax synopsis above. They respectively create a *composite type*, an *enum type*, a *range type*, a *base type*, or a *shell type*. The first four of these are discussed in turn below. A shell type is simply a placeholder for a type to be defined later; it is created by issuing CREATE TYPE with no parameters except for the type name. Shell types are needed as forward references when creating range types and base types, as discussed in those sections.

Composite Types

The first form of CREATE TYPE creates a composite type. The composite type is specified by a list of attribute names and data types. An attribute's collation can be specified too, if its data type is collatable. A composite type is essentially the same as the row type of a table, but using CREATE TYPE avoids the need to create an actual table when all that is wanted is to define a type. A stand-alone composite type is useful, for example, as the argument or return type of a function.

To be able to create a composite type, you must have USAGE privilege on all attribute types.

Enumerated Types

The second form of CREATE TYPE creates an enumerated (enum) type, as described in Section 8.7. Enum types take a list of one or more quoted labels, each of which must be less than NAMEDATALEN bytes long (64 bytes in a standard PostgreSQL build).

Range Types

The third form of CREATE TYPE creates a new range type, as described in Section 8.17.

The range type's *subtype* can be any type with an associated b-tree operator class (to determine the ordering of values for the range type). Normally the subtype's default b-tree operator class is used to determine ordering; to use a non-default operator class, specify its name with *subtype_opclass*. If the subtype is collatable, and you want to use a non-default collation in the range's ordering, specify the desired collation with the *collation* option.

The optional *canonical* function must take one argument of the range type being defined, and return a value of the same type. This is used to convert range values to a canonical form, when applicable. See Section 8.17.8 for more information. Creating a *canonical* function is a bit tricky, since it must be defined before the range type can be declared. To do this, you must first create a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command CREATE TYPE *name*, with no additional parameters. Then the function can be declared using the shell type as argument and result, and finally the range type can be declared using the same name. This automatically replaces the shell type entry with a valid range type.

The optional *subtype_diff* function must take two values of the *subtype* type as argument, and return a double precision value representing the difference between the two given values. While this is optional, providing it allows much greater efficiency of GiST indexes on columns of the range type. See Section 8.17.8 for more information.

Base Types

The fourth form of CREATE TYPE creates a new base type (scalar type). To create a new base type, you must be a superuser. (This restriction is made because an erroneous type definition could confuse

or even crash the server.)

The parameters can appear in any order, not only that illustrated above, and most are optional. You must register two or more functions (using `CREATE FUNCTION`) before defining the type. The support functions *`input_function`* and *`output_function`* are required, while the functions *`receive_function`*, *`send_function`*, *`type_modifier_input_function`*, *`type_modifier_output_function`* and *`analyze_function`* are optional. Generally these functions have to be coded in C or another low-level language.

The *`input_function`* converts the type's external textual representation to the internal representation used by the operators and functions defined for the type. *`output_function`* performs the reverse transformation. The input function can be declared as taking one argument of type `cstring`, or as taking three arguments of types `cstring`, `oid`, `integer`. The first argument is the input text as a C string, the second argument is the type's own OID (except for array types, which instead receive their element type's OID), and the third is the `typmod` of the destination column, if known (-1 will be passed if not). The input function must return a value of the data type itself. Usually, an input function should be declared STRICT; if it is not, it will be called with a NULL first parameter when reading a NULL input value. The function must still return NULL in this case, unless it raises an error. (This case is mainly meant to support domain input functions, which might need to reject NULL inputs.) The output function must be declared as taking one argument of the new data type. The output function must return type `cstring`. Output functions are not invoked for NULL values.

The optional *`receive_function`* converts the type's external binary representation to the internal representation. If this function is not supplied, the type cannot participate in binary input. The binary representation should be chosen to be cheap to convert to internal form, while being reasonably portable. (For example, the standard integer data types use network byte order as the external binary representation, while the internal representation is in the machine's native byte order.) The receive function should perform adequate checking to ensure that the value is valid. The receive function can be declared as taking one argument of type `internal`, or as taking three arguments of types `internal`, `oid`, `integer`. The first argument is a pointer to a `StringInfo` buffer holding the received byte string; the optional arguments are the same as for the text input function. The receive function must return a value of the data type itself. Usually, a receive function should be declared STRICT; if it is not, it will be called with a NULL first parameter when reading a NULL input value. The function must still return NULL in this case, unless it raises an error. (This case is mainly meant to support domain receive functions, which might need to reject NULL inputs.) Similarly, the optional *`send_function`* converts from the internal representation to the external binary representation. If this function is not supplied, the type cannot participate in binary output. The send function must be declared as taking one argument of the new data type. The send function must return type `bytea`. Send functions are not invoked for NULL values.

You should at this point be wondering how the input and output functions can be declared to have results or arguments of the new type, when they have to be created before the new type can be created. The answer is that the type should first be defined as a *shell type*, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE` *`name`*, with no additional parameters. Then the I/O functions can be defined referencing the shell type. Finally, `CREATE TYPE` with a full definition replaces the shell entry with a complete, valid type definition, after which the new type can be used normally.

The optional *`type_modifier_input_function`* and *`type_modifier_output_function`* are needed if the type supports modifiers, that is optional constraints attached to a type declaration, such as `char(5)` or `numeric(30,2)`. PostgreSQL allows user-defined types to take one or more simple constants or identifiers as modifiers. However, this information must be capable of being packed into a single non-negative integer value for storage in the system catalogs. The *`type_modifier_input_function`* is passed the declared modifier(s) in the form of a `cstring` array. It must check the values for validity (throwing an error if they are wrong), and if they are

correct, return a single non-negative `integer` value that will be stored as the column "typmod". Type modifiers will be rejected if the type does not have a *`type_modifier_input_function`*. The *`type_modifier_output_function`* converts the internal integer typmod value back to the correct form for user display. It must return a `cstring` value that is the exact string to append to the type name; for example `numeric`'s function might return `(30,2)`. It is allowed to omit the *`type_modifier_output_function`*, in which case the default display format is just the stored typmod integer value enclosed in parentheses.

The optional *`analyze_function`* performs type-specific statistics collection for columns of the data type. By default, `ANALYZE` will attempt to gather statistics using the type's "equals" and "less-than" operators, if there is a default b-tree operator class for the type. For non-scalar types this behavior is likely to be unsuitable, so it can be overridden by specifying a custom analysis function. The analysis function must be declared to take a single argument of type `internal`, and return a `boolean` result. The detailed API for analysis functions appears in `src/include/commands/vacuum.h`.

While the details of the new type's internal representation are only known to the I/O functions and other functions you create to work with the type, there are several properties of the internal representation that must be declared to PostgreSQL. Foremost of these is *`internallength`*. Base data types can be fixed-length, in which case *`internallength`* is a positive integer, or variable length, indicated by setting *`internallength`* to `VARIABLE`. (Internally, this is represented by setting `typlen` to -1.) The internal representation of all variable-length types must start with a 4-byte integer giving the total length of this value of the type.

The optional flag `PASSEDBYVALUE` indicates that values of this data type are passed by value, rather than by reference. You cannot pass by value types whose internal representation is larger than the size of the `Datum` type (4 bytes on most machines, 8 bytes on a few).

The *`alignment`* parameter specifies the storage alignment required for the data type. The allowed values equate to alignment on 1, 2, 4, or 8 byte boundaries. Note that variable-length types must have an alignment of at least 4, since they necessarily contain an `int4` as their first component.

The *`storage`* parameter allows selection of storage strategies for variable-length data types. (Only `plain` is allowed for fixed-length types.) `plain` specifies that data of the type will always be stored in-line and not compressed. `extended` specifies that the system will first try to compress a long data value, and will move the value out of the main table row if it's still too long. `external` allows the value to be moved out of the main table, but the system will not try to compress it. `main` allows compression, but discourages moving the value out of the main table. (Data items with this storage strategy might still be moved out of the main table if there is no other way to make a row fit, but they will be kept in the main table preferentially over `extended` and `external` items.)

The *`like_type`* parameter provides an alternative method for specifying the basic representation properties of a data type: copy them from some existing type. The values of *`internallength`*, *`passedbyvalue`*, *`alignment`*, and *`storage`* are copied from the named type. (It is possible, though usually undesirable, to override some of these values by specifying them along with the `LIKE` clause.) Specifying representation this way is especially useful when the low-level implementation of the new type "piggybacks" on an existing type in some fashion.

The *`category`* and *`preferred`* parameters can be used to help control which implicit cast will be applied in ambiguous situations. Each data type belongs to a category named by a single ASCII character, and each type is either "preferred" or not within its category. The parser will prefer casting to preferred types (but only from other types within the same category) when this rule is helpful in resolving overloaded functions or operators. For more details see Chapter 10. For types that have no implicit casts to or from any other types, it is sufficient to leave these settings at the defaults. However, for a group of related types that have implicit casts, it is often helpful to mark them all as belonging to a category and select one or two of the "most general" types as being preferred within the category. The *`category`* parameter is especially useful when adding a user-defined type to an existing built-in

category, such as the numeric or string types. However, it is also possible to create new entirely-user-defined type categories. Select any ASCII character other than an upper-case letter to name such a category.

A default value can be specified, in case a user wants columns of the data type to default to something other than the null value. Specify the default with the `DEFAULT` key word. (Such a default can be overridden by an explicit `DEFAULT` clause attached to a particular column.)

To indicate that a type is an array, specify the type of the array elements using the `ELEMENT` key word. For example, to define an array of 4-byte integers (`int4`), specify `ELEMENT = int4`. More details about array types appear below.

To indicate the delimiter to be used between values in the external representation of arrays of this type, *`delimiter`* can be set to a specific character. The default delimiter is the comma (`,`). Note that the delimiter is associated with the array element type, not the array type itself.

If the optional Boolean parameter *`collatable`* is true, column definitions and expressions of the type may carry collation information through use of the `COLLATE` clause. It is up to the implementations of the functions operating on the type to actually make use of the collation information; this does not happen automatically merely by marking the type collatable.

Array Types

Whenever a user-defined type is created, PostgreSQL automatically creates an associated array type, whose name consists of the element type's name prepended with an underscore, and truncated if necessary to keep it less than `NAMEDATALEN` bytes long. (If the name so generated collides with an existing type name, the process is repeated until a non-colliding name is found.) This implicitly-created array type is variable length and uses the built-in input and output functions `array_in` and `array_out`. The array type tracks any changes in its element type's owner or schema, and is dropped if the element type is.

You might reasonably ask why there is an `ELEMENT` option, if the system makes the correct array type automatically. The only case where it's useful to use `ELEMENT` is when you are making a fixed-length type that happens to be internally an array of a number of identical things, and you want to allow these things to be accessed directly by subscripting, in addition to whatever operations you plan to provide for the type as a whole. For example, type `point` is represented as just two floating-point numbers, each can be accessed using `point[0]` and `point[1]`. Note that this facility only works for fixed-length types whose internal form is exactly a sequence of identical fixed-length fields. A subscriptable variable-length type must have the generalized internal representation used by `array_in` and `array_out`. For historical reasons (i.e., this is clearly wrong but it's far too late to change it), subscripting of fixed-length array types starts from zero, rather than from one as for variable-length arrays.

Parameters

`name`

The name (optionally schema-qualified) of a type to be created.

`attribute_name`

The name of an attribute (column) for the composite type.

data_type

The name of an existing data type to become a column of the composite type.

collation

The name of an existing collation to be associated with a column of a composite type, or with a range type.

label

A string literal representing the textual label associated with one value of an enum type.

subtype

The name of the element type that the range type will represent ranges of.

subtype_operator_class

The name of a b-tree operator class for the subtype.

canonical_function

The name of the canonicalization function for the range type.

subtype_diff_function

The name of a difference function for the subtype.

input_function

The name of a function that converts data from the type's external textual form to its internal form.

output_function

The name of a function that converts data from the type's internal form to its external textual form.

receive_function

The name of a function that converts data from the type's external binary form to its internal form.

send_function

The name of a function that converts data from the type's internal form to its external binary form.

type_modifier_input_function

The name of a function that converts an array of modifier(s) for the type into internal form.

type_modifier_output_function

The name of a function that converts the internal form of the type's modifier(s) to external textual form.

analyze_function

The name of a function that performs statistical analysis for the data type.

internallength

A numeric constant that specifies the length in bytes of the new type's internal representation. The default assumption is that it is variable-length.

alignment

The storage alignment requirement of the data type. If specified, it must be `char`, `int2`, `int4`, or `double`; the default is `int4`.

storage

The storage strategy for the data type. If specified, must be `plain`, `external`, `extended`, or `main`; the default is `plain`.

like_type

The name of an existing data type that the new type will have the same representation as. The values of *internallength*, *passedbyvalue*, *alignment*, and *storage* are copied from that type, unless overridden by explicit specification elsewhere in this `CREATE TYPE` command.

category

The category code (a single ASCII character) for this type. The default is `'U'` for "user-defined type". Other standard category codes can be found in Table 48-53. You may also choose other ASCII characters in order to create custom categories.

preferred

True if this type is a preferred type within its type category, else false. The default is false. Be very careful about creating a new preferred type within an existing type category, as this could cause surprising changes in behavior.

default

The default value for the data type. If this is omitted, the default is null.

element

The type being created is an array; this specifies the type of the array elements.

delimiter

The delimiter character to be used between values in arrays made of this type.

collatable

True if this type's operations can use collation information. The default is false.

Notes

Because there are no restrictions on use of a data type once it's been created, creating a base type or range type is tantamount to granting public execute permission on the functions mentioned in the type definition. This is usually not an issue for the sorts of functions that are useful in a type definition. But you might want to think twice before designing a type in a way that would require "secret" information to be used while converting it to or from external form.

Before PostgreSQL version 8.3, the name of a generated array type was always exactly the element type's name with one underscore character (_) prepended. (Type names were therefore restricted in length to one less character than other names.) While this is still usually the case, the array type name may vary from this in case of maximum-length names or collisions with user type names that begin with underscore. Writing code that depends on this convention is therefore deprecated. Instead, use `pg_type.typarray` to locate the array type associated with a given type.

It may be advisable to avoid using type and table names that begin with underscore. While the server will change generated array type names to avoid collisions with user-given names, there is still risk of confusion, particularly with old client software that may assume that type names beginning with underscores always represent arrays.

Before PostgreSQL version 8.2, the shell-type creation syntax `CREATE TYPE` *name* did not exist. The way to create a new base type was to create its input function first. In this approach, PostgreSQL will first see the name of the new data type as the return type of the input function. The shell type is

implicitly created in this situation, and then it can be referenced in the definitions of the remaining I/O functions. This approach still works, but is deprecated and might be disallowed in some future release. Also, to avoid accidentally cluttering the catalogs with shell types as a result of simple typos in function definitions, a shell type will only be made this way when the input function is written in C.

In PostgreSQL versions before 7.3, it was customary to avoid creating a shell type at all, by replacing the functions' forward references to the type name with the placeholder pseudotype `opaque`. The `cstring` arguments and results also had to be declared as `opaque` before 7.3. To support loading of old dump files, `CREATE TYPE` will accept I/O functions declared using `opaque`, but it will issue a notice and change the function declarations to use the correct types.

Examples

This example creates a composite type and uses it in a function definition:

```
CREATE TYPE compfoo AS (f1 int, f2 text);

CREATE FUNCTION getfoo() RETURNS SETOF compfoo AS $$
    SELECT fooid, fooname FROM foo
$$ LANGUAGE SQL;
```

This example creates an enumerated type and uses it in a table definition:

```
CREATE TYPE bug_status AS ENUM ('new', 'open', 'closed');

CREATE TABLE bug (
    id serial,
    description text,
    status bug_status
);
```

This example creates a range type:

```
CREATE TYPE float8_range AS RANGE (subtype = float8, subtype_diff = float8mi);
```

This example creates the base data type `box` and then uses the type in a table definition:

```
CREATE TYPE box;

CREATE FUNCTION my_box_in_function(cstring) RETURNS box AS ... ;
CREATE FUNCTION my_box_out_function(box) RETURNS cstring AS ... ;

CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function
);

CREATE TABLE myboxes (
    id integer,
```

```
    description box
);
```

If the internal structure of `box` were an array of four `float4` elements, we might instead use:

```
CREATE TYPE box (
    INTERNALLENGTH = 16,
    INPUT = my_box_in_function,
    OUTPUT = my_box_out_function,
    ELEMENT = float4
);
```

which would allow a box value's component numbers to be accessed by subscripting. Otherwise the type behaves the same as before.

This example creates a large object type and uses it in a table definition:

```
CREATE TYPE bigobj (
    INPUT = lo_filein, OUTPUT = lo_fileout,
    INTERNALLENGTH = VARIABLE
);
CREATE TABLE big_objs (
    id integer,
    obj bigobj
);
```

More examples, including suitable input and output functions, are in Section 35.11.

Compatibility

The first form of the `CREATE TYPE` command, which creates a composite type, conforms to the SQL standard. The other forms are PostgreSQL extensions. The `CREATE TYPE` statement in the SQL standard also defines other forms that are not implemented in PostgreSQL.

The ability to create a composite type with zero attributes is a PostgreSQL-specific deviation from the standard (analogous to the same case in `CREATE TABLE`).

See Also

ALTER TYPE, CREATE DOMAIN, CREATE FUNCTION, DROP TYPE

CREATE USER

Name

CREATE USER — define a new database role

Synopsis

```
CREATE USER name [ [ WITH ] option [ ... ] ]

where option can be:

      SUPERUSER | NOSUPERUSER
    | CREATEDB | NOCREATEDB
    | CREATEROLE | NOCREATEROLE
    | CREATEUSER | NOCREATEUSER
    | INHERIT | NOINHERIT
    | LOGIN | NOLOGIN
    | REPLICATION | NOREPLICATION
    | CONNECTION LIMIT connlimit
    | [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
    | VALID UNTIL 'timestamp'
    | IN ROLE role_name [, ...]
    | IN GROUP role_name [, ...]
    | ROLE role_name [, ...]
    | ADMIN role_name [, ...]
    | USER role_name [, ...]
    | SYSID uid
```

Description

CREATE USER is now an alias for CREATE ROLE. The only difference is that when the command is spelled CREATE USER, LOGIN is assumed by default, whereas NOLOGIN is assumed when the command is spelled CREATE ROLE.

Compatibility

The CREATE USER statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

CREATE ROLE

CREATE USER MAPPING

Name

CREATE USER MAPPING — define a new mapping of a user to a foreign server

Synopsis

```
CREATE USER MAPPING FOR { user_name | USER | CURRENT_USER | PUBLIC }
    SERVER server_name
    [ OPTIONS ( option 'value' [ , ... ] ) ]
```

Description

CREATE USER MAPPING defines a mapping of a user to a foreign server. A user mapping typically encapsulates connection information that a foreign-data wrapper uses together with the information encapsulated by a foreign server to access an external data resource.

The owner of a foreign server can create user mappings for that server for any user. Also, a user can create a user mapping for his own user name if USAGE privilege on the server has been granted to the user.

Parameters

user_name

The name of an existing user that is mapped to foreign server. CURRENT_USER and USER match the name of the current user. When PUBLIC is specified, a so-called public mapping is created that is used when no user-specific mapping is applicable.

server_name

The name of an existing server for which the user mapping is to be created.

OPTIONS (*option* '*value*' [, ...])

This clause specifies the options of the user mapping. The options typically define the actual user name and password of the mapping. Option names must be unique. The allowed option names and values are specific to the server's foreign-data wrapper.

Examples

Create a user mapping for user bob, server foo:

```
CREATE USER MAPPING FOR bob SERVER foo OPTIONS (user 'bob', password 'secret');
```

Compatibility

`CREATE USER MAPPING` conforms to ISO/IEC 9075-9 (SQL/MED).

See Also

ALTER USER MAPPING, DROP USER MAPPING, CREATE FOREIGN DATA WRAPPER, CREATE SERVER

CREATE VIEW

Name

CREATE VIEW — define a new view

Synopsis

```
CREATE [ OR REPLACE ] [ TEMP | TEMPORARY ] [ RECURSIVE ] VIEW name [ ( column_name [, ...]
    [ WITH ( view_option_name [= view_option_value] [, ... ] ) ]
    AS query
    [ WITH [ CASCADED | LOCAL ] CHECK OPTION ]
```

Description

CREATE VIEW defines a view of a query. The view is not physically materialized. Instead, the query is run every time the view is referenced in a query.

CREATE OR REPLACE VIEW is similar, but if a view of the same name already exists, it is replaced. The new query must generate the same columns that were generated by the existing view query (that is, the same column names in the same order and with the same data types), but it may add additional columns to the end of the list. The calculations giving rise to the output columns may be completely different.

If a schema name is given (for example, CREATE VIEW myschema.myview ...) then the view is created in the specified schema. Otherwise it is created in the current schema. Temporary views exist in a special schema, so a schema name cannot be given when creating a temporary view. The name of the view must be distinct from the name of any other view, table, sequence, index or foreign table in the same schema.

Parameters

TEMPORARY or TEMP

If specified, the view is created as a temporary view. Temporary views are automatically dropped at the end of the current session. Existing permanent relations with the same name are not visible to the current session while the temporary view exists, unless they are referenced with schema-qualified names.

If any of the tables referenced by the view are temporary, the view is created as a temporary view (whether TEMPORARY is specified or not).

RECURSIVE

Creates a recursive view. The syntax

CREATE RECURSIVE VIEW *name* (*columns*) AS SELECT ...;
is equivalent to

CREATE VIEW *name* AS WITH RECURSIVE *name* (*columns*) AS (SELECT ...) SELECT *columns* FROM *n*
A view column list must be specified for a recursive view.

name

The name (optionally schema-qualified) of a view to be created.

column_name

An optional list of names to be used for columns of the view. If not given, the column names are deduced from the query.

WITH (*view_option_name* [= *view_option_value*] [, ...])

This clause specifies optional parameters for a view; the following parameters are supported:

check_option (string)

This parameter may be either local or cascaded, and is equivalent to specifying WITH [CASCADED | LOCAL] CHECK OPTION (see below). This option can be changed on existing views using ALTER VIEW.

security_barrier (string)

This should be used if the view is intended to provide row-level security. See Section 38.5 for full details.

query

A SELECT or VALUES command which will provide the columns and rows of the view.

WITH [CASCADED | LOCAL] CHECK OPTION

This option controls the behavior of automatically updatable views. When this option is specified, INSERT and UPDATE commands on the view will be checked to ensure that new rows satisfy the view-defining condition (that is, the new rows are checked to ensure that they are visible through the view). If they are not, the update will be rejected. If the CHECK OPTION is not specified, INSERT and UPDATE commands on the view are allowed to create rows that are not visible through the view. The following check options are supported:

LOCAL

New rows are only checked against the conditions defined directly in the view itself. Any conditions defined on underlying base views are not checked (unless they also specify the CHECK OPTION).

CASCADED

New rows are checked against the conditions of the view and all underlying base views. If the CHECK OPTION is specified, and neither LOCAL nor CASCADED is specified, then CASCADED is assumed.

The CHECK OPTION may not be used with RECURSIVE views.

Note that the CHECK OPTION is only supported on views that are automatically updatable, and do not have INSTEAD OF triggers or INSTEAD rules. If an automatically updatable view is defined on top of a base view that has INSTEAD OF triggers, then the LOCAL CHECK OPTION may be used to check the conditions on the automatically updatable view, but the conditions on the base view with INSTEAD OF triggers will not be checked (a cascaded check option will not cascade down to a trigger-updatable view, and any check options defined directly on a trigger-updatable view will be ignored). If the view or any of its base relations has an INSTEAD rule that causes the INSERT or UPDATE command to be rewritten, then all check options will be ignored in the

rewritten query, including any checks from automatically updatable views defined on top of the relation with the INSTEAD rule.

Notes

Use the DROP VIEW statement to drop views.

Be careful that the names and types of the view's columns will be assigned the way you want. For example:

```
CREATE VIEW vista AS SELECT 'Hello World';
```

is bad form in two ways: the column name defaults to ?column?, and the column data type defaults to unknown. If you want a string literal in a view's result, use something like:

```
CREATE VIEW vista AS SELECT text 'Hello World' AS hello;
```

Access to tables referenced in the view is determined by permissions of the view owner. In some cases, this can be used to provide secure but restricted access to the underlying tables. However, not all views are secure against tampering; see Section 38.5 for details. Functions called in the view are treated the same as if they had been called directly from the query using the view. Therefore the user of a view must have permissions to call all functions used by the view.

When CREATE OR REPLACE VIEW is used on an existing view, only the view's defining SELECT rule is changed. Other view properties, including ownership, permissions, and non-SELECT rules, remain unchanged. You must own the view to replace it (this includes being a member of the owning role).

Updatable Views

Simple views are automatically updatable: the system will allow INSERT, UPDATE and DELETE statements to be used on the view in the same way as on a regular table. A view is automatically updatable if it satisfies all of the following conditions:

- The view must have exactly one entry in its FROM list, which must be a table or another updatable view.
- The view definition must not contain WITH, DISTINCT, GROUP BY, HAVING, LIMIT, or OFFSET clauses at the top level.
- The view definition must not contain set operations (UNION, INTERSECT or EXCEPT) at the top level.
- The view's select list must not contain any aggregates, window functions or set-returning functions.

An automatically updatable view may contain a mix of updatable and non-updatable columns. A column is updatable if it is a simple reference to an updatable column of the underlying base relation; otherwise the column is read-only, and an error will be raised if an INSERT or UPDATE statement attempts to assign a value to it.

If the view is automatically updatable the system will convert any INSERT, UPDATE or DELETE statement on the view into the corresponding statement on the underlying base relation.

If an automatically updatable view contains a `WHERE` condition, the condition restricts which rows of the base relation are available to be modified by `UPDATE` and `DELETE` statements on the view. However, an `UPDATE` is allowed to change a row so that it no longer satisfies the `WHERE` condition, and thus is no longer visible through the view. Similarly, an `INSERT` command can potentially insert base-relation rows that do not satisfy the `WHERE` condition and thus are not visible through the view. The `CHECK OPTION` may be used to prevent `INSERT` and `UPDATE` commands from creating such rows that are not visible through the view.

If an automatically updatable view is marked with the `security_barrier` property then all the view's `WHERE` conditions (and any conditions using operators which are marked as `LEAKPROOF`) will always be evaluated before any conditions that a user of the view has added. See Section 38.5 for full details. Note that, due to this, rows which are not ultimately returned (because they do not pass the user's `WHERE` conditions) may still end up being locked. `EXPLAIN` can be used to see which conditions are applied at the relation level (and therefore do not lock rows) and which are not.

A more complex view that does not satisfy all these conditions is read-only by default: the system will not allow an insert, update, or delete on the view. You can get the effect of an updatable view by creating `INSTEAD OF` triggers on the view, which must convert attempted inserts, etc. on the view into appropriate actions on other tables. For more information see CREATE TRIGGER. Another possibility is to create rules (see CREATE RULE), but in practice triggers are easier to understand and use correctly.

Note that the user performing the insert, update or delete on the view must have the corresponding insert, update or delete privilege on the view. In addition the view's owner must have the relevant privileges on the underlying base relations, but the user performing the update does not need any permissions on the underlying base relations (see Section 38.5).

Examples

Create a view consisting of all comedy films:

```
CREATE VIEW comedies AS
    SELECT *
    FROM films
    WHERE kind = 'Comedy';
```

This will create a view containing the columns that are in the `film` table at the time of view creation. Though `*` was used to create the view, columns added later to the table will not be part of the view.

Create a view with `LOCAL CHECK OPTION`:

```
CREATE VIEW universal_comedies AS
    SELECT *
    FROM comedies
    WHERE classification = 'U'
    WITH LOCAL CHECK OPTION;
```

This will create a view based on the `comedies` view, showing only films with `kind = 'Comedy'` and `classification = 'U'`. Any attempt to `INSERT` or `UPDATE` a row in the view will be rejected if the new row doesn't have `classification = 'U'`, but the film `kind` will not be checked.

Create a view with `CASCADED CHECK OPTION`:

```
CREATE VIEW pg_comedies AS
    SELECT *
```

```
    FROM comedies
    WHERE classification = 'PG'
    WITH CASCADED CHECK OPTION;
```

This will create a view that checks both the `kind` and `classification` of new rows.

Create a view with a mix of updatable and non-updatable columns:

```
CREATE VIEW comedies AS
    SELECT f.*,
           country_code_to_name(f.country_code) AS country,
           (SELECT avg(r.rating)
            FROM user_ratings r
            WHERE r.film_id = f.id) AS avg_rating
    FROM films f
    WHERE f.kind = 'Comedy';
```

This view will support `INSERT`, `UPDATE` and `DELETE`. All the columns from the `films` table will be updatable, whereas the computed columns `country` and `avg_rating` will be read-only.

Create a recursive view consisting of the numbers from 1 to 100:

```
CREATE RECURSIVE VIEW nums_1_100 (n) AS
    VALUES (1)
UNION ALL
    SELECT n+1 FROM nums_1_100 WHERE n < 100;
```

Compatibility

`CREATE OR REPLACE VIEW` is a PostgreSQL language extension. So is the concept of a temporary view. The `WITH ( ... )` clause is an extension as well.

See Also

ALTER VIEW, DROP VIEW, CREATE MATERIALIZED VIEW

DEALLOCATE

Name

`DEALLOCATE` — deallocate a prepared statement

Synopsis

```
DEALLOCATE [ PREPARE ] { name | ALL }
```

Description

`DEALLOCATE` is used to deallocate a previously prepared SQL statement. If you do not explicitly deallocate a prepared statement, it is deallocated when the session ends.

For more information on prepared statements, see PREPARE.

Parameters

`PREPARE`

This key word is ignored.

`name`

The name of the prepared statement to deallocate.

`ALL`

Deallocate all prepared statements.

Compatibility

The SQL standard includes a `DEALLOCATE` statement, but it is only for use in embedded SQL.

See Also

EXECUTE, PREPARE

DECLARE

Name

DECLARE — define a cursor

Synopsis

```
DECLARE name [ BINARY ] [ INSENSITIVE ] [ [ NO ] SCROLL ]
    CURSOR [ { WITH | WITHOUT } HOLD ] FOR query
```

Description

DECLARE allows a user to create cursors, which can be used to retrieve a small number of rows at a time out of a larger query. After the cursor is created, rows are fetched from it using FETCH.

> **Note:** This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 40.7.

Parameters

name

The name of the cursor to be created.

BINARY

Causes the cursor to return data in binary rather than in text format.

INSENSITIVE

Indicates that data retrieved from the cursor should be unaffected by updates to the table(s) underlying the cursor that occur after the cursor is created. In PostgreSQL, this is the default behavior; so this key word has no effect and is only accepted for compatibility with the SQL standard.

SCROLL
NO SCROLL

SCROLL specifies that the cursor can be used to retrieve rows in a nonsequential fashion (e.g., backward). Depending upon the complexity of the query's execution plan, specifying SCROLL might impose a performance penalty on the query's execution time. NO SCROLL specifies that the cursor cannot be used to retrieve rows in a nonsequential fashion. The default is to allow scrolling in some cases; this is not the same as specifying SCROLL. See *Notes* for details.

WITH HOLD
WITHOUT HOLD

WITH HOLD specifies that the cursor can continue to be used after the transaction that created it successfully commits. WITHOUT HOLD specifies that the cursor cannot be used outside of the

transaction that created it. If neither `WITHOUT HOLD` nor `WITH HOLD` is specified, `WITHOUT HOLD` is the default.

query

A SELECT or VALUES command which will provide the rows to be returned by the cursor.

The key words `BINARY`, `INSENSITIVE`, and `SCROLL` can appear in any order.

Notes

Normal cursors return data in text format, the same as a `SELECT` would produce. The `BINARY` option specifies that the cursor should return data in binary format. This reduces conversion effort for both the server and client, at the cost of more programmer effort to deal with platform-dependent binary data formats. As an example, if a query returns a value of one from an integer column, you would get a string of `1` with a default cursor, whereas with a binary cursor you would get a 4-byte field containing the internal representation of the value (in big-endian byte order).

Binary cursors should be used carefully. Many applications, including psql, are not prepared to handle binary cursors and expect data to come back in the text format.

> **Note:** When the client application uses the "extended query" protocol to issue a `FETCH` command, the Bind protocol message specifies whether data is to be retrieved in text or binary format. This choice overrides the way that the cursor is defined. The concept of a binary cursor as such is thus obsolete when using extended query protocol — any cursor can be treated as either text or binary.

Unless `WITH HOLD` is specified, the cursor created by this command can only be used within the current transaction. Thus, `DECLARE` without `WITH HOLD` is useless outside a transaction block: the cursor would survive only to the completion of the statement. Therefore PostgreSQL reports an error if such a command is used outside a transaction block. Use BEGIN and COMMIT (or ROLLBACK) to define a transaction block.

If `WITH HOLD` is specified and the transaction that created the cursor successfully commits, the cursor can continue to be accessed by subsequent transactions in the same session. (But if the creating transaction is aborted, the cursor is removed.) A cursor created with `WITH HOLD` is closed when an explicit `CLOSE` command is issued on it, or the session ends. In the current implementation, the rows represented by a held cursor are copied into a temporary file or memory area so that they remain available for subsequent transactions.

`WITH HOLD` may not be specified when the query includes `FOR UPDATE` or `FOR SHARE`.

The `SCROLL` option should be specified when defining a cursor that will be used to fetch backwards. This is required by the SQL standard. However, for compatibility with earlier versions, PostgreSQL will allow backward fetches without `SCROLL`, if the cursor's query plan is simple enough that no extra overhead is needed to support it. However, application developers are advised not to rely on using backward fetches from a cursor that has not been created with `SCROLL`. If `NO SCROLL` is specified, then backward fetches are disallowed in any case.

Backward fetches are also disallowed when the query includes `FOR UPDATE` or `FOR SHARE`; therefore `SCROLL` may not be specified in this case.

> **Caution**
>
> Scrollable and WITH HOLD cursors may give unexpected results if they invoke any volatile functions (see Section 35.6). When a previously fetched row is re-fetched, the functions might be re-executed, perhaps leading to results different from the first time. One workaround for such cases is to declare the cursor WITH HOLD and commit the transaction before reading any rows from it. This will force the entire output of the cursor to be materialized in temporary storage, so that volatile functions are executed exactly once for each row.

If the cursor's query includes FOR UPDATE or FOR SHARE, then returned rows are locked at the time they are first fetched, in the same way as for a regular SELECT command with these options. In addition, the returned rows will be the most up-to-date versions; therefore these options provide the equivalent of what the SQL standard calls a "sensitive cursor". (Specifying INSENSITIVE together with FOR UPDATE or FOR SHARE is an error.)

> **Caution**
>
> It is generally recommended to use FOR UPDATE if the cursor is intended to be used with UPDATE ... WHERE CURRENT OF or DELETE ... WHERE CURRENT OF. Using FOR UPDATE prevents other sessions from changing the rows between the time they are fetched and the time they are updated. Without FOR UPDATE, a subsequent WHERE CURRENT OF command will have no effect if the row was changed since the cursor was created.
>
> Another reason to use FOR UPDATE is that without it, a subsequent WHERE CURRENT OF might fail if the cursor query does not meet the SQL standard's rules for being "simply updatable" (in particular, the cursor must reference just one table and not use grouping or ORDER BY). Cursors that are not simply updatable might work, or might not, depending on plan choice details; so in the worst case, an application might work in testing and then fail in production.
>
> The main reason not to use FOR UPDATE with WHERE CURRENT OF is if you need the cursor to be scrollable, or to be insensitive to the subsequent updates (that is, continue to show the old data). If this is a requirement, pay close heed to the caveats shown above.

The SQL standard only makes provisions for cursors in embedded SQL. The PostgreSQL server does not implement an OPEN statement for cursors; a cursor is considered to be open when it is declared. However, ECPG, the embedded SQL preprocessor for PostgreSQL, supports the standard SQL cursor conventions, including those involving DECLARE and OPEN statements.

You can see all available cursors by querying the pg_cursors system view.

Examples

To declare a cursor:

```
DECLARE liahona CURSOR FOR SELECT * FROM films;
```

See FETCH for more examples of cursor usage.

Compatibility

The SQL standard says that it is implementation-dependent whether cursors are sensitive to concurrent updates of the underlying data by default. In PostgreSQL, cursors are insensitive by default, and can be made sensitive by specifying `FOR UPDATE`. Other products may work differently.

The SQL standard allows cursors only in embedded SQL and in modules. PostgreSQL permits cursors to be used interactively.

Binary cursors are a PostgreSQL extension.

See Also

CLOSE, FETCH, MOVE

DELETE

Name

DELETE — delete rows of a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
DELETE FROM [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    [ USING using_list ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ RETURNING * | output_expression [ [ AS ] output_name ] [, ...] ]
```

Description

DELETE deletes rows that satisfy the WHERE clause from the specified table. If the WHERE clause is absent, the effect is to delete all rows in the table. The result is a valid, but empty table.

> **Tip:** TRUNCATE is a PostgreSQL extension that provides a faster mechanism to remove all rows from a table.

There are two ways to delete rows in a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the USING clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes DELETE to compute and return value(s) based on each row actually deleted. Any expression using the table's columns, and/or columns of other tables mentioned in USING, can be computed. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the DELETE privilege on the table to delete from it, as well as the SELECT privilege for any table in the USING clause or whose values are read in the *condition*.

Parameters

with_query

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the DELETE query. See Section 7.8 and SELECT for details.

table_name

The name (optionally schema-qualified) of the table to delete rows from. If ONLY is specified before the table name, matching rows are deleted from the named table only. If ONLY is not specified, matching rows are also deleted from any tables inheriting from the named table. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `DELETE FROM foo AS f`, the remainder of the `DELETE` statement must refer to this table as `f` not `foo`.

using_list

A list of table expressions, allowing columns from other tables to appear in the `WHERE` condition. This is similar to the list of tables that can be specified in the *FROM Clause* of a `SELECT` statement; for example, an alias for the table name can be specified. Do not repeat the target table in the *using_list*, unless you wish to set up a self-join.

condition

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be deleted.

cursor_name

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be deleted is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `DELETE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See DECLARE for more information about using cursors with `WHERE CURRENT OF`.

output_expression

An expression to be computed and returned by the `DELETE` command after each row is deleted. The expression can use any column names of the table named by *table_name* or table(s) listed in `USING`. Write `*` to return all columns.

output_name

A name to use for a returned column.

Outputs

On successful completion, a `DELETE` command returns a command tag of the form

```
DELETE count
```

The *count* is the number of rows deleted. Note that the number may be less than the number of rows that matched the *condition* when deletes were suppressed by a `BEFORE DELETE` trigger. If *count* is 0, no rows were deleted by the query (this is not considered an error).

If the `DELETE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) deleted by the command.

Notes

PostgreSQL lets you reference columns of other tables in the `WHERE` condition by specifying the other tables in the `USING` clause. For example, to delete all films produced by a given producer, one can do:

```
DELETE FROM films USING producers
  WHERE producer_id = producers.id AND producers.name = 'foo';
```

What is essentially happening here is a join between `films` and `producers`, with all successfully joined `films` rows being marked for deletion. This syntax is not standard. A more standard way to do it is:

```
DELETE FROM films
  WHERE producer_id IN (SELECT id FROM producers WHERE name = 'foo');
```

In some cases the join style is easier to write or faster to execute than the sub-select style.

Examples

Delete all films but musicals:

```
DELETE FROM films WHERE kind <> 'Musical';
```

Clear the table `films`:

```
DELETE FROM films;
```

Delete completed tasks, returning full details of the deleted rows:

```
DELETE FROM tasks WHERE status = 'DONE' RETURNING *;
```

Delete the row of `tasks` on which the cursor `c_tasks` is currently positioned:

```
DELETE FROM tasks WHERE CURRENT OF c_tasks;
```

Compatibility

This command conforms to the SQL standard, except that the `USING` and `RETURNING` clauses are PostgreSQL extensions, as is the ability to use `WITH` with `DELETE`.

DISCARD

Name

DISCARD — discard session state

Synopsis

```
DISCARD { ALL | PLANS | SEQUENCES | TEMPORARY | TEMP }
```

Description

DISCARD releases internal resources associated with a database session. This command is useful for partially or fully resetting the session's state. There are several subcommands to release different types of resources; the DISCARD ALL variant subsumes all the others, and also resets additional state.

Parameters

PLANS

Releases all cached query plans, forcing re-planning to occur the next time the associated prepared statement is used.

SEQUENCES

Discards all cached sequence-related state, including currval()/lastval() information and any preallocated sequence values that have not yet been returned by nextval(). (See CREATE SEQUENCE for a description of preallocated sequence values.)

TEMPORARY or TEMP

Drops all temporary tables created in the current session.

ALL

Releases all temporary resources associated with the current session and resets the session to its initial state. Currently, this has the same effect as executing the following sequence of statements:

```
SET SESSION AUTHORIZATION DEFAULT;
RESET ALL;
DEALLOCATE ALL;
CLOSE ALL;
UNLISTEN *;
SELECT pg_advisory_unlock_all();
DISCARD PLANS;
DISCARD SEQUENCES;
DISCARD TEMP;
```

Notes

DISCARD ALL cannot be executed inside a transaction block.

Compatibility

`DISCARD` is a PostgreSQL extension.

DO

Name

DO — execute an anonymous code block

Synopsis

```
DO [ LANGUAGE lang_name ] code
```

Description

DO executes an anonymous code block, or in other words a transient anonymous function in a procedural language.

The code block is treated as though it were the body of a function with no parameters, returning void. It is parsed and executed a single time.

The optional LANGUAGE clause can be written either before or after the code block.

Parameters

code

The procedural language code to be executed. This must be specified as a string literal, just as in CREATE FUNCTION. Use of a dollar-quoted literal is recommended.

lang_name

The name of the procedural language the code is written in. If omitted, the default is plpgsql.

Notes

The procedural language to be used must already have been installed into the current database by means of CREATE LANGUAGE. plpgsql is installed by default, but other languages are not.

The user must have USAGE privilege for the procedural language, or must be a superuser if the language is untrusted. This is the same privilege requirement as for creating a function in the language.

Examples

Grant all privileges on all views in schema public to role webuser:

```
DO $$DECLARE r record;
BEGIN
    FOR r IN SELECT table_schema, table_name FROM information_schema.tables
             WHERE table_type = 'VIEW' AND table_schema = 'public'
    LOOP
        EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) || '.' || quote_ident(r.t
    END LOOP;
```

```
END$$;
```

Compatibility

There is no `DO` statement in the SQL standard.

See Also

CREATE LANGUAGE

DROP AGGREGATE

Name

DROP AGGREGATE — remove an aggregate function

Synopsis

```
DROP AGGREGATE [ IF EXISTS ] name ( aggregate_signature ) [ CASCADE | RESTRICT ]

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ] [ argname ] argtype [ , .
```

Description

DROP AGGREGATE removes an existing aggregate function. To execute this command the current user must be the owner of the aggregate function.

Parameters

IF EXISTS

Do not throw an error if the aggregate does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing aggregate function.

argmode

The mode of an argument: IN or VARIADIC. If omitted, the default is IN.

argname

The name of an argument. Note that DROP AGGREGATE does not actually pay any attention to argument names, since only the argument data types are needed to determine the aggregate function's identity.

argtype

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write * in place of the list of argument specifications. To reference an ordered-set aggregate function, write ORDER BY between the direct and aggregated argument specifications.

CASCADE

Automatically drop objects that depend on the aggregate function.

RESTRICT

Refuse to drop the aggregate function if any objects depend on it. This is the default.

Notes

Alternative syntaxes for referencing ordered-set aggregates are described under ALTER AGGREGATE.

Examples

To remove the aggregate function `myavg` for type `integer`:

```
DROP AGGREGATE myavg(integer);
```

To remove the hypothetical-set aggregate function `myrank`, which takes an arbitrary list of ordering columns and a matching list of direct arguments:

```
DROP AGGREGATE myrank(VARIADIC "any" ORDER BY VARIADIC "any");
```

Compatibility

There is no `DROP AGGREGATE` statement in the SQL standard.

See Also

ALTER AGGREGATE, CREATE AGGREGATE

DROP CAST

Name

DROP CAST — remove a cast

Synopsis

```
DROP CAST [ IF EXISTS ] (source_type AS target_type) [ CASCADE | RESTRICT ]
```

Description

DROP CAST removes a previously defined cast.

To be able to drop a cast, you must own the source or the target data type. These are the same privileges that are required to create a cast.

Parameters

IF EXISTS

Do not throw an error if the cast does not exist. A notice is issued in this case.

source_type

The name of the source data type of the cast.

target_type

The name of the target data type of the cast.

CASCADE
RESTRICT

These key words do not have any effect, since there are no dependencies on casts.

Examples

To drop the cast from type text to type int:

```
DROP CAST (text AS int);
```

Compatibility

The DROP CAST command conforms to the SQL standard.

See Also

CREATE CAST

DROP COLLATION

Name

DROP COLLATION — remove a collation

Synopsis

```
DROP COLLATION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP COLLATION removes a previously defined collation. To be able to drop a collation, you must own the collation.

Parameters

IF EXISTS

Do not throw an error if the collation does not exist. A notice is issued in this case.

name

The name of the collation. The collation name can be schema-qualified.

CASCADE

Automatically drop objects that depend on the collation.

RESTRICT

Refuse to drop the collation if any objects depend on it. This is the default.

Examples

To drop the collation named german:

```
DROP COLLATION german;
```

Compatibility

The DROP COLLATION command conforms to the SQL standard, apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER COLLATION, CREATE COLLATION

DROP CONVERSION

Name

DROP CONVERSION — remove a conversion

Synopsis

```
DROP CONVERSION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP CONVERSION removes a previously defined conversion. To be able to drop a conversion, you must own the conversion.

Parameters

IF EXISTS

Do not throw an error if the conversion does not exist. A notice is issued in this case.

name

The name of the conversion. The conversion name can be schema-qualified.

CASCADE
RESTRICT

These key words do not have any effect, since there are no dependencies on conversions.

Examples

To drop the conversion named myname:

```
DROP CONVERSION myname;
```

Compatibility

There is no DROP CONVERSION statement in the SQL standard, but a DROP TRANSLATION statement that goes along with the CREATE TRANSLATION statement that is similar to the CREATE CONVERSION statement in PostgreSQL.

See Also

ALTER CONVERSION, CREATE CONVERSION

DROP DATABASE

Name

`DROP DATABASE` — remove a database

Synopsis

```
DROP DATABASE [ IF EXISTS ] name
```

Description

`DROP DATABASE` drops a database. It removes the catalog entries for the database and deletes the directory containing the data. It can only be executed by the database owner. Also, it cannot be executed while you or anyone else are connected to the target database. (Connect to `postgres` or any other database to issue this command.)

`DROP DATABASE` cannot be undone. Use it with care!

Parameters

`IF EXISTS`

Do not throw an error if the database does not exist. A notice is issued in this case.

`name`

The name of the database to remove.

Notes

`DROP DATABASE` cannot be executed inside a transaction block.

This command cannot be executed while connected to the target database. Thus, it might be more convenient to use the program dropdb instead, which is a wrapper around this command.

Compatibility

There is no `DROP DATABASE` statement in the SQL standard.

See Also

CREATE DATABASE

DROP DOMAIN

Name

DROP DOMAIN — remove a domain

Synopsis

```
DROP DOMAIN [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP DOMAIN removes a domain. Only the owner of a domain can remove it.

Parameters

IF EXISTS

Do not throw an error if the domain does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing domain.

CASCADE

Automatically drop objects that depend on the domain (such as table columns).

RESTRICT

Refuse to drop the domain if any objects depend on it. This is the default.

Examples

To remove the domain box:

```
DROP DOMAIN box;
```

Compatibility

This command conforms to the SQL standard, except for the IF EXISTS option, which is a PostgreSQL extension.

See Also

CREATE DOMAIN, ALTER DOMAIN

DROP EVENT TRIGGER

Name

`DROP EVENT TRIGGER` — remove an event trigger

Synopsis

```
DROP EVENT TRIGGER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

`DROP EVENT TRIGGER` removes an existing event trigger. To execute this command, the current user must be the owner of the event trigger.

Parameters

`IF EXISTS`

Do not throw an error if the event trigger does not exist. A notice is issued in this case.

`name`

The name of the event trigger to remove.

`CASCADE`

Automatically drop objects that depend on the trigger.

`RESTRICT`

Refuse to drop the trigger if any objects depend on it. This is the default.

Examples

Destroy the trigger `snitch`:

```
DROP EVENT TRIGGER snitch;
```

Compatibility

There is no `DROP EVENT TRIGGER` statement in the SQL standard.

See Also

CREATE EVENT TRIGGER, ALTER EVENT TRIGGER

DROP EXTENSION

Name

DROP EXTENSION — remove an extension

Synopsis

```
DROP EXTENSION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP EXTENSION removes extensions from the database. Dropping an extension causes its component objects to be dropped as well.

You must own the extension to use DROP EXTENSION.

Parameters

IF EXISTS

Do not throw an error if the extension does not exist. A notice is issued in this case.

name

The name of an installed extension.

CASCADE

Automatically drop objects that depend on the extension.

RESTRICT

Refuse to drop the extension if any objects depend on it (other than its own member objects and other extensions listed in the same DROP command). This is the default.

Examples

To remove the extension hstore from the current database:

```
DROP EXTENSION hstore;
```

This command will fail if any of hstore's objects are in use in the database, for example if any tables have columns of the hstore type. Add the CASCADE option to forcibly remove those dependent objects as well.

Compatibility

DROP EXTENSION is a PostgreSQL extension.

See Also

CREATE EXTENSION, ALTER EXTENSION

DROP FOREIGN DATA WRAPPER

Name

`DROP FOREIGN DATA WRAPPER` — remove a foreign-data wrapper

Synopsis

```
DROP FOREIGN DATA WRAPPER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

`DROP FOREIGN DATA WRAPPER` removes an existing foreign-data wrapper. To execute this command, the current user must be the owner of the foreign-data wrapper.

Parameters

`IF EXISTS`

Do not throw an error if the foreign-data wrapper does not exist. A notice is issued in this case.

`name`

The name of an existing foreign-data wrapper.

`CASCADE`

Automatically drop objects that depend on the foreign-data wrapper (such as servers).

`RESTRICT`

Refuse to drop the foreign-data wrappers if any objects depend on it. This is the default.

Examples

Drop the foreign-data wrapper `dbi`:

```
DROP FOREIGN DATA WRAPPER dbi;
```

Compatibility

`DROP FOREIGN DATA WRAPPER` conforms to ISO/IEC 9075-9 (SQL/MED). The `IF EXISTS` clause is a PostgreSQL extension.

See Also

CREATE FOREIGN DATA WRAPPER, ALTER FOREIGN DATA WRAPPER

DROP FOREIGN TABLE

Name

DROP FOREIGN TABLE — remove a foreign table

Synopsis

```
DROP FOREIGN TABLE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP FOREIGN TABLE removes a foreign table. Only the owner of a foreign table can remove it.

Parameters

IF EXISTS

Do not throw an error if the foreign table does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the foreign table to drop.

CASCADE

Automatically drop objects that depend on the foreign table (such as views).

RESTRICT

Refuse to drop the foreign table if any objects depend on it. This is the default.

Examples

To destroy two foreign tables, films and distributors:

```
DROP FOREIGN TABLE films, distributors;
```

Compatibility

This command conforms to the ISO/IEC 9075-9 (SQL/MED), except that the standard only allows one foreign table to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER FOREIGN TABLE, CREATE FOREIGN TABLE

DROP FUNCTION

Name

DROP FUNCTION — remove a function

Synopsis

```
DROP FUNCTION [ IF EXISTS ] name ( [ [ argmode ] [ argname ] argtype [, ...] ] )
    [ CASCADE | RESTRICT ]
```

Description

DROP FUNCTION removes the definition of an existing function. To execute this command the user must be the owner of the function. The argument types to the function must be specified, since several different functions can exist with the same name and different argument lists.

Parameters

IF EXISTS

Do not throw an error if the function does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing function.

argmode

The mode of an argument: IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that DROP FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname

The name of an argument. Note that DROP FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type(s) of the function's arguments (optionally schema-qualified), if any.

CASCADE

Automatically drop objects that depend on the function (such as operators or triggers).

RESTRICT

Refuse to drop the function if any objects depend on it. This is the default.

Examples

This command removes the square root function:

```
DROP FUNCTION sqrt(integer);
```

Compatibility

A `DROP FUNCTION` statement is defined in the SQL standard, but it is not compatible with this command.

See Also

CREATE FUNCTION, ALTER FUNCTION

DROP GROUP

Name

`DROP GROUP` — remove a database role

Synopsis

```
DROP GROUP [ IF EXISTS ] name [, ...]
```

Description

`DROP GROUP` is now an alias for DROP ROLE.

Compatibility

There is no `DROP GROUP` statement in the SQL standard.

See Also

DROP ROLE

DROP INDEX

Name

DROP INDEX — remove an index

Synopsis

```
DROP INDEX [ CONCURRENTLY ] [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP INDEX` drops an existing index from the database system. To execute this command you must be the owner of the index.

Parameters

`CONCURRENTLY`

Drop the index without locking out concurrent selects, inserts, updates, and deletes on the index's table. A normal `DROP INDEX` acquires exclusive lock on the table, blocking other accesses until the index drop can be completed. With this option, the command instead waits until conflicting transactions have completed.

There are several caveats to be aware of when using this option. Only one index name can be specified, and the `CASCADE` option is not supported. (Thus, an index that supports a `UNIQUE` or `PRIMARY KEY` constraint cannot be dropped this way.) Also, regular `DROP INDEX` commands can be performed within a transaction block, but `DROP INDEX CONCURRENTLY` cannot.

`IF EXISTS`

Do not throw an error if the index does not exist. A notice is issued in this case.

`name`

The name (optionally schema-qualified) of an index to remove.

`CASCADE`

Automatically drop objects that depend on the index.

`RESTRICT`

Refuse to drop the index if any objects depend on it. This is the default.

Examples

This command will remove the index `title_idx`:

```
DROP INDEX title_idx;
```

Compatibility

`DROP INDEX` is a PostgreSQL language extension. There are no provisions for indexes in the SQL standard.

See Also

CREATE INDEX

DROP LANGUAGE

Name

DROP LANGUAGE — remove a procedural language

Synopsis

```
DROP [ PROCEDURAL ] LANGUAGE [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP LANGUAGE removes the definition of a previously registered procedural language. You must be a superuser or the owner of the language to use DROP LANGUAGE.

> **Note:** As of PostgreSQL 9.1, most procedural languages have been made into "extensions", and should therefore be removed with DROP EXTENSION not DROP LANGUAGE.

Parameters

IF EXISTS

Do not throw an error if the language does not exist. A notice is issued in this case.

name

The name of an existing procedural language. For backward compatibility, the name can be enclosed by single quotes.

CASCADE

Automatically drop objects that depend on the language (such as functions in the language).

RESTRICT

Refuse to drop the language if any objects depend on it. This is the default.

Examples

This command removes the procedural language plsample:

```
DROP LANGUAGE plsample;
```

Compatibility

There is no `DROP LANGUAGE` statement in the SQL standard.

See Also

ALTER LANGUAGE, CREATE LANGUAGE, droplang

DROP MATERIALIZED VIEW

Name

`DROP MATERIALIZED VIEW` — remove a materialized view

Synopsis

```
DROP MATERIALIZED VIEW [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

`DROP MATERIALIZED VIEW` drops an existing materialized view. To execute this command you must be the owner of the materialized view.

Parameters

`IF EXISTS`

Do not throw an error if the materialized view does not exist. A notice is issued in this case.

`name`

The name (optionally schema-qualified) of the materialized view to remove.

`CASCADE`

Automatically drop objects that depend on the materialized view (such as other materialized views, or regular views).

`RESTRICT`

Refuse to drop the materialized view if any objects depend on it. This is the default.

Examples

This command will remove the materialized view called `order_summary`:

```
DROP MATERIALIZED VIEW order_summary;
```

Compatibility

`DROP MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

CREATE MATERIALIZED VIEW, ALTER MATERIALIZED VIEW, REFRESH MATERIALIZED VIEW

DROP OPERATOR

Name

`DROP OPERATOR` — remove an operator

Synopsis

```
DROP OPERATOR [ IF EXISTS ] name ( { left_type | NONE } , { right_type | NONE } ) [ CASCADE
```

Description

`DROP OPERATOR` drops an existing operator from the database system. To execute this command you must be the owner of the operator.

Parameters

`IF EXISTS`

Do not throw an error if the operator does not exist. A notice is issued in this case.

`name`

The name (optionally schema-qualified) of an existing operator.

`left_type`

The data type of the operator's left operand; write `NONE` if the operator has no left operand.

`right_type`

The data type of the operator's right operand; write `NONE` if the operator has no right operand.

`CASCADE`

Automatically drop objects that depend on the operator.

`RESTRICT`

Refuse to drop the operator if any objects depend on it. This is the default.

Examples

Remove the power operator `a^b` for type `integer`:

```
DROP OPERATOR ^ (integer, integer);
```

Remove the left unary bitwise complement operator `~b` for type `bit`:

```
DROP OPERATOR ~ (none, bit);
```

Remove the right unary factorial operator `x!` for type `bigint`:

```
DROP OPERATOR ! (bigint, none);
```

Compatibility

There is no `DROP OPERATOR` statement in the SQL standard.

See Also

CREATE OPERATOR, ALTER OPERATOR

DROP OPERATOR CLASS

Name

DROP OPERATOR CLASS — remove an operator class

Synopsis

```
DROP OPERATOR CLASS [ IF EXISTS ] name USING index_method [ CASCADE | RESTRICT ]
```

Description

DROP OPERATOR CLASS drops an existing operator class. To execute this command you must be the owner of the operator class.

DROP OPERATOR CLASS does not drop any of the operators or functions referenced by the class. If there are any indexes depending on the operator class, you will need to specify CASCADE for the drop to complete.

Parameters

IF EXISTS

Do not throw an error if the operator class does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing operator class.

index_method

The name of the index access method the operator class is for.

CASCADE

Automatically drop objects that depend on the operator class.

RESTRICT

Refuse to drop the operator class if any objects depend on it. This is the default.

Notes

DROP OPERATOR CLASS will not drop the operator family containing the class, even if there is nothing else left in the family (in particular, in the case where the family was implicitly created by CREATE OPERATOR CLASS). An empty operator family is harmless, but for the sake of tidiness you might wish to remove the family with DROP OPERATOR FAMILY; or perhaps better, use DROP OPERATOR FAMILY in the first place.

Examples

Remove the B-tree operator class `widget_ops`:

```
DROP OPERATOR CLASS widget_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator class. Add `CASCADE` to drop such indexes along with the operator class.

Compatibility

There is no `DROP OPERATOR CLASS` statement in the SQL standard.

See Also

ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR FAMILY

DROP OPERATOR FAMILY

Name

DROP OPERATOR FAMILY — remove an operator family

Synopsis

```
DROP OPERATOR FAMILY [ IF EXISTS ] name USING index_method [ CASCADE | RESTRICT ]
```

Description

`DROP OPERATOR FAMILY` drops an existing operator family. To execute this command you must be the owner of the operator family.

`DROP OPERATOR FAMILY` includes dropping any operator classes contained in the family, but it does not drop any of the operators or functions referenced by the family. If there are any indexes depending on operator classes within the family, you will need to specify `CASCADE` for the drop to complete.

Parameters

`IF EXISTS`

Do not throw an error if the operator family does not exist. A notice is issued in this case.

`name`

The name (optionally schema-qualified) of an existing operator family.

`index_method`

The name of the index access method the operator family is for.

`CASCADE`

Automatically drop objects that depend on the operator family.

`RESTRICT`

Refuse to drop the operator family if any objects depend on it. This is the default.

Examples

Remove the B-tree operator family `float_ops`:

```
DROP OPERATOR FAMILY float_ops USING btree;
```

This command will not succeed if there are any existing indexes that use operator classes within the family. Add `CASCADE` to drop such indexes along with the operator family.

Compatibility

There is no `DROP OPERATOR FAMILY` statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, CREATE OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

DROP OWNED

Name

DROP OWNED — remove database objects owned by a database role

Synopsis

```
DROP OWNED BY name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP OWNED drops all the objects within the current database that are owned by one of the specified roles. Any privileges granted to the given roles on objects in the current database and on shared objects (databases, tablespaces) will also be revoked.

Parameters

name

The name of a role whose objects will be dropped, and whose privileges will be revoked.

CASCADE

Automatically drop objects that depend on the affected objects.

RESTRICT

Refuse to drop the objects owned by a role if any other database objects depend on one of the affected objects. This is the default.

Notes

DROP OWNED is often used to prepare for the removal of one or more roles. Because DROP OWNED only affects the objects in the current database, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

Using the CASCADE option might make the command recurse to objects owned by other users.

The REASSIGN OWNED command is an alternative that reassigns the ownership of all the database objects owned by one or more roles.

Databases and tablespaces owned by the role(s) will not be removed.

Compatibility

The DROP OWNED statement is a PostgreSQL extension.

See Also

REASSIGN OWNED, DROP ROLE

DROP ROLE

Name

DROP ROLE — remove a database role

Synopsis

```
DROP ROLE [ IF EXISTS ] name [, ...]
```

Description

DROP ROLE removes the specified role(s). To drop a superuser role, you must be a superuser yourself; to drop non-superuser roles, you must have CREATEROLE privilege.

A role cannot be removed if it is still referenced in any database of the cluster; an error will be raised if so. Before dropping the role, you must drop all the objects it owns (or reassign their ownership) and revoke any privileges the role has been granted. The REASSIGN OWNED and DROP OWNED commands can be useful for this purpose.

However, it is not necessary to remove role memberships involving the role; DROP ROLE automatically revokes any memberships of the target role in other roles, and of other roles in the target role. The other roles are not dropped nor otherwise affected.

Parameters

IF EXISTS

Do not throw an error if the role does not exist. A notice is issued in this case.

name

The name of the role to remove.

Notes

PostgreSQL includes a program dropuser that has the same functionality as this command (in fact, it calls this command) but can be run from the command shell.

Examples

To drop a role:

```
DROP ROLE jonathan;
```

Compatibility

The SQL standard defines `DROP ROLE`, but it allows only one role to be dropped at a time, and it specifies different privilege requirements than PostgreSQL uses.

See Also

CREATE ROLE, ALTER ROLE, SET ROLE

DROP RULE

Name

DROP RULE — remove a rewrite rule

Synopsis

```
DROP RULE [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

Description

DROP RULE drops a rewrite rule.

Parameters

IF EXISTS

Do not throw an error if the rule does not exist. A notice is issued in this case.

name

The name of the rule to drop.

table_name

The name (optionally schema-qualified) of the table or view that the rule applies to.

CASCADE

Automatically drop objects that depend on the rule.

RESTRICT

Refuse to drop the rule if any objects depend on it. This is the default.

Examples

To drop the rewrite rule newrule:

```
DROP RULE newrule ON mytable;
```

Compatibility

DROP RULE is a PostgreSQL language extension, as is the entire query rewrite system.

See Also

CREATE RULE, ALTER RULE

DROP SCHEMA

Name

DROP SCHEMA — remove a schema

Synopsis

```
DROP SCHEMA [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP SCHEMA removes schemas from the database.

A schema can only be dropped by its owner or a superuser. Note that the owner can drop the schema (and thereby all contained objects) even if he does not own some of the objects within the schema.

Parameters

IF EXISTS

Do not throw an error if the schema does not exist. A notice is issued in this case.

name

The name of a schema.

CASCADE

Automatically drop objects (tables, functions, etc.) that are contained in the schema.

RESTRICT

Refuse to drop the schema if it contains any objects. This is the default.

Examples

To remove schema mystuff from the database, along with everything it contains:

```
DROP SCHEMA mystuff CASCADE;
```

Compatibility

DROP SCHEMA is fully conforming with the SQL standard, except that the standard only allows one schema to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER SCHEMA, CREATE SCHEMA

DROP SEQUENCE

Name

DROP SEQUENCE — remove a sequence

Synopsis

```
DROP SEQUENCE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP SEQUENCE removes sequence number generators. A sequence can only be dropped by its owner or a superuser.

Parameters

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of a sequence.

CASCADE

Automatically drop objects that depend on the sequence.

RESTRICT

Refuse to drop the sequence if any objects depend on it. This is the default.

Examples

To remove the sequence serial:

```
DROP SEQUENCE serial;
```

Compatibility

DROP SEQUENCE conforms to the SQL standard, except that the standard only allows one sequence to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

CREATE SEQUENCE, ALTER SEQUENCE

DROP SERVER

Name

DROP SERVER — remove a foreign server descriptor

Synopsis

```
DROP SERVER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP SERVER removes an existing foreign server descriptor. To execute this command, the current user must be the owner of the server.

Parameters

IF EXISTS

Do not throw an error if the server does not exist. A notice is issued in this case.

name

The name of an existing server.

CASCADE

Automatically drop objects that depend on the server (such as user mappings).

RESTRICT

Refuse to drop the server if any objects depend on it. This is the default.

Examples

Drop a server foo if it exists:

```
DROP SERVER IF EXISTS foo;
```

Compatibility

DROP SERVER conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a PostgreSQL extension.

See Also

CREATE SERVER, ALTER SERVER

DROP TABLE

Name

DROP TABLE — remove a table

Synopsis

```
DROP TABLE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP TABLE removes tables from the database. Only the table owner, the schema owner, and superuser can drop a table. To empty a table of rows without destroying the table, use DELETE or TRUNCATE.

DROP TABLE always removes any indexes, rules, triggers, and constraints that exist for the target table. However, to drop a table that is referenced by a view or a foreign-key constraint of another table, CASCADE must be specified. (CASCADE will remove a dependent view entirely, but in the foreign-key case it will only remove the foreign-key constraint, not the other table entirely.)

Parameters

IF EXISTS

Do not throw an error if the table does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the table to drop.

CASCADE

Automatically drop objects that depend on the table (such as views).

RESTRICT

Refuse to drop the table if any objects depend on it. This is the default.

Examples

To destroy two tables, films and distributors:

```
DROP TABLE films, distributors;
```

Compatibility

This command conforms to the SQL standard, except that the standard only allows one table to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER TABLE, CREATE TABLE

DROP TABLESPACE

Name

DROP TABLESPACE — remove a tablespace

Synopsis

```
DROP TABLESPACE [ IF EXISTS ] name
```

Description

DROP TABLESPACE removes a tablespace from the system.

A tablespace can only be dropped by its owner or a superuser. The tablespace must be empty of all database objects before it can be dropped. It is possible that objects in other databases might still reside in the tablespace even if no objects in the current database are using the tablespace. Also, if the tablespace is listed in the temp_tablespaces setting of any active session, the DROP might fail due to temporary files residing in the tablespace.

Parameters

IF EXISTS

Do not throw an error if the tablespace does not exist. A notice is issued in this case.

name

The name of a tablespace.

Notes

DROP TABLESPACE cannot be executed inside a transaction block.

Examples

To remove tablespace mystuff from the system:

```
DROP TABLESPACE mystuff;
```

Compatibility

DROP TABLESPACE is a PostgreSQL extension.

See Also

CREATE TABLESPACE, ALTER TABLESPACE

DROP TEXT SEARCH CONFIGURATION

Name

DROP TEXT SEARCH CONFIGURATION — remove a text search configuration

Synopsis

```
DROP TEXT SEARCH CONFIGURATION [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP TEXT SEARCH CONFIGURATION drops an existing text search configuration. To execute this command you must be the owner of the configuration.

Parameters

IF EXISTS

Do not throw an error if the text search configuration does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search configuration.

CASCADE

Automatically drop objects that depend on the text search configuration.

RESTRICT

Refuse to drop the text search configuration if any objects depend on it. This is the default.

Examples

Remove the text search configuration my_english:

```
DROP TEXT SEARCH CONFIGURATION my_english;
```

This command will not succeed if there are any existing indexes that reference the configuration in to_tsvector calls. Add CASCADE to drop such indexes along with the text search configuration.

Compatibility

There is no DROP TEXT SEARCH CONFIGURATION statement in the SQL standard.

See Also

ALTER TEXT SEARCH CONFIGURATION, CREATE TEXT SEARCH CONFIGURATION

DROP TEXT SEARCH DICTIONARY

Name

DROP TEXT SEARCH DICTIONARY — remove a text search dictionary

Synopsis

```
DROP TEXT SEARCH DICTIONARY [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

`DROP TEXT SEARCH DICTIONARY` drops an existing text search dictionary. To execute this command you must be the owner of the dictionary.

Parameters

`IF EXISTS`

Do not throw an error if the text search dictionary does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search dictionary.

`CASCADE`

Automatically drop objects that depend on the text search dictionary.

`RESTRICT`

Refuse to drop the text search dictionary if any objects depend on it. This is the default.

Examples

Remove the text search dictionary `english`:

```
DROP TEXT SEARCH DICTIONARY english;
```

This command will not succeed if there are any existing text search configurations that use the dictionary. Add `CASCADE` to drop such configurations along with the dictionary.

Compatibility

There is no `DROP TEXT SEARCH DICTIONARY` statement in the SQL standard.

See Also

ALTER TEXT SEARCH DICTIONARY, CREATE TEXT SEARCH DICTIONARY

DROP TEXT SEARCH PARSER

Name

DROP TEXT SEARCH PARSER — remove a text search parser

Synopsis

```
DROP TEXT SEARCH PARSER [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP TEXT SEARCH PARSER drops an existing text search parser. You must be a superuser to use this command.

Parameters

IF EXISTS

Do not throw an error if the text search parser does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search parser.

CASCADE

Automatically drop objects that depend on the text search parser.

RESTRICT

Refuse to drop the text search parser if any objects depend on it. This is the default.

Examples

Remove the text search parser my_parser:

```
DROP TEXT SEARCH PARSER my_parser;
```

This command will not succeed if there are any existing text search configurations that use the parser. Add CASCADE to drop such configurations along with the parser.

Compatibility

There is no DROP TEXT SEARCH PARSER statement in the SQL standard.

See Also

ALTER TEXT SEARCH PARSER, CREATE TEXT SEARCH PARSER

DROP TEXT SEARCH TEMPLATE

Name

DROP TEXT SEARCH TEMPLATE — remove a text search template

Synopsis

```
DROP TEXT SEARCH TEMPLATE [ IF EXISTS ] name [ CASCADE | RESTRICT ]
```

Description

DROP TEXT SEARCH TEMPLATE drops an existing text search template. You must be a superuser to use this command.

Parameters

IF EXISTS

Do not throw an error if the text search template does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of an existing text search template.

CASCADE

Automatically drop objects that depend on the text search template.

RESTRICT

Refuse to drop the text search template if any objects depend on it. This is the default.

Examples

Remove the text search template thesaurus:

```
DROP TEXT SEARCH TEMPLATE thesaurus;
```

This command will not succeed if there are any existing text search dictionaries that use the template. Add CASCADE to drop such dictionaries along with the template.

Compatibility

There is no DROP TEXT SEARCH TEMPLATE statement in the SQL standard.

See Also

ALTER TEXT SEARCH TEMPLATE, CREATE TEXT SEARCH TEMPLATE

DROP TRIGGER

Name

DROP TRIGGER — remove a trigger

Synopsis

```
DROP TRIGGER [ IF EXISTS ] name ON table_name [ CASCADE | RESTRICT ]
```

Description

DROP TRIGGER removes an existing trigger definition. To execute this command, the current user must be the owner of the table for which the trigger is defined.

Parameters

IF EXISTS

Do not throw an error if the trigger does not exist. A notice is issued in this case.

name

The name of the trigger to remove.

table_name

The name (optionally schema-qualified) of the table for which the trigger is defined.

CASCADE

Automatically drop objects that depend on the trigger.

RESTRICT

Refuse to drop the trigger if any objects depend on it. This is the default.

Examples

Destroy the trigger if_dist_exists on the table films:

```
DROP TRIGGER if_dist_exists ON films;
```

Compatibility

The DROP TRIGGER statement in PostgreSQL is incompatible with the SQL standard. In the SQL standard, trigger names are not local to tables, so the command is simply DROP TRIGGER *name*.

See Also

CREATE TRIGGER

DROP TYPE

Name

DROP TYPE — remove a data type

Synopsis

```
DROP TYPE [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP TYPE removes a user-defined data type. Only the owner of a type can remove it.

Parameters

IF EXISTS

Do not throw an error if the type does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the data type to remove.

CASCADE

Automatically drop objects that depend on the type (such as table columns, functions, operators).

RESTRICT

Refuse to drop the type if any objects depend on it. This is the default.

Examples

To remove the data type box:

```
DROP TYPE box;
```

Compatibility

This command is similar to the corresponding command in the SQL standard, apart from the IF EXISTS option, which is a PostgreSQL extension. But note that much of the CREATE TYPE command and the data type extension mechanisms in PostgreSQL differ from the SQL standard.

See Also

ALTER TYPE, CREATE TYPE

DROP USER

Name

`DROP USER` — remove a database role

Synopsis

```
DROP USER [ IF EXISTS ] name [, ...]
```

Description

`DROP USER` is now an alias for DROP ROLE.

Compatibility

The `DROP USER` statement is a PostgreSQL extension. The SQL standard leaves the definition of users to the implementation.

See Also

DROP ROLE

DROP USER MAPPING

Name

DROP USER MAPPING — remove a user mapping for a foreign server

Synopsis

```
DROP USER MAPPING [ IF EXISTS ] FOR { user_name | USER | CURRENT_USER | PUBLIC } SERVER s
```

Description

DROP USER MAPPING removes an existing user mapping from foreign server.

The owner of a foreign server can drop user mappings for that server for any user. Also, a user can drop a user mapping for his own user name if USAGE privilege on the server has been granted to the user.

Parameters

IF EXISTS

Do not throw an error if the user mapping does not exist. A notice is issued in this case.

user_name

User name of the mapping. CURRENT_USER and USER match the name of the current user. PUBLIC is used to match all present and future user names in the system.

server_name

Server name of the user mapping.

Examples

Drop a user mapping bob, server foo if it exists:

```
DROP USER MAPPING IF EXISTS FOR bob SERVER foo;
```

Compatibility

DROP USER MAPPING conforms to ISO/IEC 9075-9 (SQL/MED). The IF EXISTS clause is a PostgreSQL extension.

See Also

CREATE USER MAPPING, ALTER USER MAPPING

DROP VIEW

Name

DROP VIEW — remove a view

Synopsis

```
DROP VIEW [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

Description

DROP VIEW drops an existing view. To execute this command you must be the owner of the view.

Parameters

IF EXISTS

Do not throw an error if the view does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the view to remove.

CASCADE

Automatically drop objects that depend on the view (such as other views).

RESTRICT

Refuse to drop the view if any objects depend on it. This is the default.

Examples

This command will remove the view called kinds:

```
DROP VIEW kinds;
```

Compatibility

This command conforms to the SQL standard, except that the standard only allows one view to be dropped per command, and apart from the IF EXISTS option, which is a PostgreSQL extension.

See Also

ALTER VIEW, CREATE VIEW

END

Name

END — commit the current transaction

Synopsis

```
END [ WORK | TRANSACTION ]
```

Description

END commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs. This command is a PostgreSQL extension that is equivalent to COMMIT.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Notes

Use ROLLBACK to abort a transaction.

Issuing END when not inside a transaction does no harm, but it will provoke a warning message.

Examples

To commit the current transaction and make all changes permanent:

```
END;
```

Compatibility

END is a PostgreSQL extension that provides functionality equivalent to COMMIT, which is specified in the SQL standard.

See Also

BEGIN, COMMIT, ROLLBACK

EXECUTE

Name

EXECUTE — execute a prepared statement

Synopsis

```
EXECUTE name [ ( parameter [, ...] ) ]
```

Description

EXECUTE is used to execute a previously prepared statement. Since prepared statements only exist for the duration of a session, the prepared statement must have been created by a PREPARE statement executed earlier in the current session.

If the PREPARE statement that created the statement specified some parameters, a compatible set of parameters must be passed to the EXECUTE statement, or else an error is raised. Note that (unlike functions) prepared statements are not overloaded based on the type or number of their parameters; the name of a prepared statement must be unique within a database session.

For more information on the creation and usage of prepared statements, see PREPARE.

Parameters

name

The name of the prepared statement to execute.

parameter

The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

Outputs

The command tag returned by EXECUTE is that of the prepared statement, and not EXECUTE.

Examples

Examples are given in the *Examples* section of the PREPARE documentation.

Compatibility

The SQL standard includes an EXECUTE statement, but it is only for use in embedded SQL. This version of the EXECUTE statement also uses a somewhat different syntax.

See Also

DEALLOCATE, PREPARE

EXPLAIN

Name

EXPLAIN — show the execution plan of a statement

Synopsis

```
EXPLAIN [ ( option [, ...] ) ] statement
EXPLAIN [ ANALYZE ] [ VERBOSE ] statement

where option can be one of:

    ANALYZE [ boolean ]
    VERBOSE [ boolean ]
    COSTS [ boolean ]
    BUFFERS [ boolean ]
    TIMING [ boolean ]
    FORMAT { TEXT | XML | JSON | YAML }
```

Description

This command displays the execution plan that the PostgreSQL planner generates for the supplied statement. The execution plan shows how the table(s) referenced by the statement will be scanned — by plain sequential scan, index scan, etc. — and if multiple tables are referenced, what join algorithms will be used to bring together the required rows from each input table.

The most critical part of the display is the estimated statement execution cost, which is the planner's guess at how long it will take to run the statement (measured in cost units that are arbitrary, but conventionally mean disk page fetches). Actually two numbers are shown: the start-up cost before the first row can be returned, and the total cost to return all the rows. For most queries the total cost is what matters, but in contexts such as a subquery in EXISTS, the planner will choose the smallest start-up cost instead of the smallest total cost (since the executor will stop after getting one row, anyway). Also, if you limit the number of rows to return with a LIMIT clause, the planner makes an appropriate interpolation between the endpoint costs to estimate which plan is really the cheapest.

The ANALYZE option causes the statement to be actually executed, not only planned. Then actual run time statistics are added to the display, including the total elapsed time expended within each plan node (in milliseconds) and the total number of rows it actually returned. This is useful for seeing whether the planner's estimates are close to reality.

> **Important:** Keep in mind that the statement is actually executed when the ANALYZE option is used. Although EXPLAIN will discard any output that a SELECT would return, other side effects of the statement will happen as usual. If you wish to use EXPLAIN ANALYZE on an INSERT, UPDATE, DELETE, CREATE TABLE AS, or EXECUTE statement without letting the command affect your data, use this approach:
>
> ```
> BEGIN;
> EXPLAIN ANALYZE ...;
> ROLLBACK;
> ```

Only the `ANALYZE` and `VERBOSE` options can be specified, and only in that order, without surrounding the option list in parentheses. Prior to PostgreSQL 9.0, the unparenthesized syntax was the only one supported. It is expected that all new options will be supported only in the parenthesized syntax.

Parameters

`ANALYZE`

Carry out the command and show actual run times and other statistics. This parameter defaults to `FALSE`.

`VERBOSE`

Display additional information regarding the plan. Specifically, include the output column list for each node in the plan tree, schema-qualify table and function names, always label variables in expressions with their range table alias, and always print the name of each trigger for which statistics are displayed. This parameter defaults to `FALSE`.

`COSTS`

Include information on the estimated startup and total cost of each plan node, as well as the estimated number of rows and the estimated width of each row. This parameter defaults to `TRUE`.

`BUFFERS`

Include information on buffer usage. Specifically, include the number of shared blocks hit, read, dirtied, and written, the number of local blocks hit, read, dirtied, and written, and the number of temp blocks read and written. A *hit* means that a read was avoided because the block was found already in cache when needed. Shared blocks contain data from regular tables and indexes; local blocks contain data from temporary tables and indexes; while temp blocks contain short-term working data used in sorts, hashes, Materialize plan nodes, and similar cases. The number of blocks *dirtied* indicates the number of previously unmodified blocks that were changed by this query; while the number of blocks *written* indicates the number of previously-dirtied blocks evicted from cache by this backend during query processing. The number of blocks shown for an upper-level node includes those used by all its child nodes. In text format, only non-zero values are printed. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `FALSE`.

`TIMING`

Include actual startup time and time spent in each node in the output. The overhead of repeatedly reading the system clock can slow down the query significantly on some systems, so it may be useful to set this parameter to `FALSE` when only actual row counts, and not exact times, are needed. Run time of the entire statement is always measured, even when node-level timing is turned off with this option. This parameter may only be used when `ANALYZE` is also enabled. It defaults to `TRUE`.

`FORMAT`

Specify the output format, which can be TEXT, XML, JSON, or YAML. Non-text output contains the same information as the text output format, but is easier for programs to parse. This parameter defaults to `TEXT`.

boolean

Specifies whether the selected option should be turned on or off. You can write `TRUE`, `ON`, or `1` to enable the option, and `FALSE`, `OFF`, or `0` to disable it. The *boolean* value can also be omitted, in which case `TRUE` is assumed.

statement

Any `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `VALUES`, `EXECUTE`, `DECLARE`, `CREATE TABLE AS`, or `CREATE MATERIALIZED VIEW AS` statement, whose execution plan you wish to see.

Outputs

The command's result is a textual description of the plan selected for the *statement*, optionally annotated with execution statistics. Section 14.1 describes the information provided.

Notes

In order to allow the PostgreSQL query planner to make reasonably informed decisions when optimizing queries, the `pg_statistic` data should be up-to-date for all tables used in the query. Normally the autovacuum daemon will take care of that automatically. But if a table has recently had substantial changes in its contents, you might need to do a manual ANALYZE rather than wait for autovacuum to catch up with the changes.

In order to measure the run-time cost of each node in the execution plan, the current implementation of `EXPLAIN ANALYZE` adds profiling overhead to query execution. As a result, running `EXPLAIN ANALYZE` on a query can sometimes take significantly longer than executing the query normally. The amount of overhead depends on the nature of the query, as well as the platform being used. The worst case occurs for plan nodes that in themselves require very little time per execution, and on machines that have relatively slow operating system calls for obtaining the time of day.

Examples

To show the plan for a simple query on a table with a single `integer` column and 10000 rows:

```
EXPLAIN SELECT * FROM foo;

                       QUERY PLAN
-------------------------------------------------------------
 Seq Scan on foo  (cost=0.00..155.00 rows=10000 width=4)
(1 row)
```

Here is the same query, with JSON output formatting:

```
EXPLAIN (FORMAT JSON) SELECT * FROM foo;
           QUERY PLAN
--------------------------------
 [                              +
   {                            +
     "Plan": {                  +
       "Node Type": "Seq Scan",+
       "Relation Name": "foo", +
```

```
       "Alias": "foo",          +
       "Startup Cost": 0.00,    +
       "Total Cost": 155.00,    +
       "Plan Rows": 10000,      +
       "Plan Width": 4          +
     }                          +
   }                            +
 ]
(1 row)
```

If there is an index and we use a query with an indexable `WHERE` condition, `EXPLAIN` might show a different plan:

```
EXPLAIN SELECT * FROM foo WHERE i = 4;

                          QUERY PLAN
---------------------------------------------------------------
 Index Scan using fi on foo  (cost=0.00..5.98 rows=1 width=4)
   Index Cond: (i = 4)
(2 rows)
```

Here is the same query, but in YAML format:

```
EXPLAIN (FORMAT YAML) SELECT * FROM foo WHERE i='4';
          QUERY PLAN
-------------------------------
 - Plan:                      +
     Node Type: "Index Scan"  +
     Scan Direction: "Forward"+
     Index Name: "fi"         +
     Relation Name: "foo"     +
     Alias: "foo"             +
     Startup Cost: 0.00       +
     Total Cost: 5.98         +
     Plan Rows: 1             +
     Plan Width: 4            +
     Index Cond: "(i = 4)"
(1 row)
```

XML format is left as an exercise for the reader.

Here is the same plan with cost estimates suppressed:

```
EXPLAIN (COSTS FALSE) SELECT * FROM foo WHERE i = 4;

        QUERY PLAN
---------------------------
 Index Scan using fi on foo
   Index Cond: (i = 4)
(2 rows)
```

Here is an example of a query plan for a query using an aggregate function:

```
EXPLAIN SELECT sum(i) FROM foo WHERE i < 10;
```

```
                              QUERY PLAN
-----------------------------------------------------------------------
 Aggregate  (cost=23.93..23.93 rows=1 width=4)
   ->  Index Scan using fi on foo  (cost=0.00..23.92 rows=6 width=4)
         Index Cond: (i < 10)
(3 rows)
```

Here is an example of using `EXPLAIN EXECUTE` to display the execution plan for a prepared query:

```
PREPARE query(int, int) AS SELECT sum(bar) FROM test
    WHERE id > $1 AND id < $2
    GROUP BY foo;

EXPLAIN ANALYZE EXECUTE query(100, 200);

                                                              QUERY PLAN
---------------------------------------------------------------------------------------------
 HashAggregate  (cost=9.54..9.54 rows=1 width=8) (actual time=0.156..0.161 rows=11 loops
   Group Key: foo
   ->  Index Scan using test_pkey on test  (cost=0.29..9.29 rows=50 width=8) (actual tim
         Index Cond: ((id > $1) AND (id < $2))
 Planning time: 0.197 ms
 Execution time: 0.225 ms
(6 rows)
```

Of course, the specific numbers shown here depend on the actual contents of the tables involved. Also note that the numbers, and even the selected query strategy, might vary between PostgreSQL releases due to planner improvements. In addition, the `ANALYZE` command uses random sampling to estimate data statistics; therefore, it is possible for cost estimates to change after a fresh run of `ANALYZE`, even if the actual distribution of data in the table has not changed.

Compatibility

There is no `EXPLAIN` statement defined in the SQL standard.

See Also

ANALYZE

FETCH

Name

FETCH — retrieve rows from a query using a cursor

Synopsis

```
FETCH [ direction [ FROM | IN ] ] cursor_name

where direction can be empty or one of:

    NEXT
    PRIOR
    FIRST
    LAST
    ABSOLUTE count
    RELATIVE count
    count
    ALL
    FORWARD
    FORWARD count
    FORWARD ALL
    BACKWARD
    BACKWARD count
    BACKWARD ALL
```

Description

FETCH retrieves rows using a previously-created cursor.

A cursor has an associated position, which is used by FETCH. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result. When created, a cursor is positioned before the first row. After fetching some rows, the cursor is positioned on the row most recently retrieved. If FETCH runs off the end of the available rows then the cursor is left positioned after the last row, or before the first row if fetching backward. FETCH ALL or FETCH BACKWARD ALL will always leave the cursor positioned after the last row or before the first row.

The forms NEXT, PRIOR, FIRST, LAST, ABSOLUTE, RELATIVE fetch a single row after moving the cursor appropriately. If there is no such row, an empty result is returned, and the cursor is left positioned before the first row or after the last row as appropriate.

The forms using FORWARD and BACKWARD retrieve the indicated number of rows moving in the forward or backward direction, leaving the cursor positioned on the last-returned row (or after/before all rows, if the *count* exceeds the number of rows available).

RELATIVE 0, FORWARD 0, and BACKWARD 0 all request fetching the current row without moving the cursor, that is, re-fetching the most recently fetched row. This will succeed unless the cursor is positioned before the first row or after the last row; in which case, no row is returned.

> **Note:** This page describes usage of cursors at the SQL command level. If you are trying to use cursors inside a PL/pgSQL function, the rules are different — see Section 40.7.

Parameters

direction

direction defines the fetch direction and number of rows to fetch. It can be one of the following:

`NEXT`

Fetch the next row. This is the default if *direction* is omitted.

`PRIOR`

Fetch the prior row.

`FIRST`

Fetch the first row of the query (same as `ABSOLUTE 1`).

`LAST`

Fetch the last row of the query (same as `ABSOLUTE -1`).

`ABSOLUTE` *count*

Fetch the *count*'th row of the query, or the `abs(`*count*`)`'th row from the end if *count* is negative. Position before first row or after last row if *count* is out of range; in particular, `ABSOLUTE 0` positions before the first row.

`RELATIVE` *count*

Fetch the *count*'th succeeding row, or the `abs(`*count*`)`'th prior row if *count* is negative. `RELATIVE 0` re-fetches the current row, if any.

count

Fetch the next *count* rows (same as `FORWARD` *count*).

`ALL`

Fetch all remaining rows (same as `FORWARD ALL`).

`FORWARD`

Fetch the next row (same as `NEXT`).

`FORWARD` *count*

Fetch the next *count* rows. `FORWARD 0` re-fetches the current row.

`FORWARD ALL`

Fetch all remaining rows.

`BACKWARD`

Fetch the prior row (same as `PRIOR`).

`BACKWARD` *count*

Fetch the prior *count* rows (scanning backwards). `BACKWARD 0` re-fetches the current row.

`BACKWARD ALL`

Fetch all prior rows (scanning backwards).

count

count is a possibly-signed integer constant, determining the location or number of rows to fetch. For FORWARD and BACKWARD cases, specifying a negative *count* is equivalent to changing the sense of FORWARD and BACKWARD.

cursor_name

An open cursor's name.

Outputs

On successful completion, a FETCH command returns a command tag of the form

```
FETCH count
```

The *count* is the number of rows fetched (possibly zero). Note that in psql, the command tag will not actually be displayed, since psql displays the fetched rows instead.

Notes

The cursor should be declared with the SCROLL option if one intends to use any variants of FETCH other than FETCH NEXT or FETCH FORWARD with a positive count. For simple queries PostgreSQL will allow backwards fetch from cursors not declared with SCROLL, but this behavior is best not relied on. If the cursor is declared with NO SCROLL, no backward fetches are allowed.

ABSOLUTE fetches are not any faster than navigating to the desired row with a relative move: the underlying implementation must traverse all the intermediate rows anyway. Negative absolute fetches are even worse: the query must be read to the end to find the last row, and then traversed backward from there. However, rewinding to the start of the query (as with FETCH ABSOLUTE 0) is fast.

DECLARE is used to define a cursor. Use MOVE to change cursor position without retrieving data.

Examples

The following example traverses a table using a cursor:

```
BEGIN WORK;

-- Set up a cursor:
DECLARE liahona SCROLL CURSOR FOR SELECT * FROM films;

-- Fetch the first 5 rows in the cursor liahona:
FETCH FORWARD 5 FROM liahona;

 code  |          title          | did | date_prod  |   kind   |  len
-------+-------------------------+-----+------------+----------+-------
 BL101 | The Third Man           | 101 | 1949-12-23 | Drama    | 01:44
 BL102 | The African Queen       | 101 | 1951-08-11 | Romantic | 01:43
 JL201 | Une Femme est une Femme | 102 | 1961-03-12 | Romantic | 01:25
 P_301 | Vertigo                 | 103 | 1958-11-14 | Action   | 02:08
 P_302 | Becket                  | 103 | 1964-02-03 | Drama    | 02:28

-- Fetch the previous row:
```

```
FETCH PRIOR FROM liahona;

 code  |  title  | did | date_prod  |  kind  |  len
-------+---------+-----+------------+--------+-------
 P_301 | Vertigo | 103 | 1958-11-14 | Action | 02:08

-- Close the cursor and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

Compatibility

The SQL standard defines `FETCH` for use in embedded SQL only. The variant of `FETCH` described here returns the data as if it were a `SELECT` result rather than placing it in host variables. Other than this point, `FETCH` is fully upward-compatible with the SQL standard.

The `FETCH` forms involving `FORWARD` and `BACKWARD`, as well as the forms `FETCH` *`count`* and `FETCH ALL`, in which `FORWARD` is implicit, are PostgreSQL extensions.

The SQL standard allows only `FROM` preceding the cursor name; the option to use `IN`, or to leave them out altogether, is an extension.

See Also

CLOSE, DECLARE, MOVE

GRANT

Name

GRANT — define access privileges

Synopsis

```
GRANT { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON { [ TABLE ] table_name [, ...]
         | ALL TABLES IN SCHEMA schema_name [, ...] }
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name [, ...] )
    [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
    ON [ TABLE ] table_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON { SEQUENCE sequence_name [, ...]
         | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL [ PRIVILEGES ] }
    ON DATABASE database_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON DOMAIN domain_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN DATA WRAPPER fdw_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN SERVER server_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { EXECUTE | ALL [ PRIVILEGES ] }
    ON { FUNCTION function_name ( [ [ argmode ] [ arg_name ] arg_type [, ...] ] ) [, ...]
         | ALL FUNCTIONS IN SCHEMA schema_name [, ...] }
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON LANGUAGE lang_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
    ON LARGE OBJECT loid [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
```

```
    ON SCHEMA schema_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { CREATE | ALL [ PRIVILEGES ] }
    ON TABLESPACE tablespace_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE type_name [, ...]
    TO { [ GROUP ] role_name | PUBLIC } [, ...] [ WITH GRANT OPTION ]

GRANT role_name [, ...] TO role_name [, ...] [ WITH ADMIN OPTION ]
```

Description

The GRANT command has two basic variants: one that grants privileges on a database object (table, column, view, foreign table, sequence, database, foreign-data wrapper, foreign server, function, procedural language, schema, or tablespace), and one that grants membership in a role. These variants are similar in many ways, but they are different enough to be described separately.

GRANT on Database Objects

This variant of the GRANT command gives specific privileges on a database object to one or more roles. These privileges are added to those already granted, if any.

There is also an option to grant privileges on all objects of the same type within one or more schemas. This functionality is currently supported only for tables, sequences, and functions (but note that ALL TABLES is considered to include views and foreign tables).

The key word PUBLIC indicates that the privileges are to be granted to all roles, including those that might be created later. PUBLIC can be thought of as an implicitly defined group that always includes all roles. Any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC.

If WITH GRANT OPTION is specified, the recipient of the privilege can in turn grant it to others. Without a grant option, the recipient cannot do that. Grant options cannot be granted to PUBLIC.

There is no need to grant privileges to the owner of an object (usually the user that created it), as the owner has all privileges by default. (The owner could, however, choose to revoke some of his own privileges for safety.)

The right to drop an object, or to alter its definition in any way, is not treated as a grantable privilege; it is inherent in the owner, and cannot be granted or revoked. (However, a similar effect can be obtained by granting or revoking membership in the role that owns the object; see below.) The owner implicitly has all grant options for the object, too.

PostgreSQL grants default privileges on some types of objects to PUBLIC. No privileges are granted to PUBLIC by default on tables, columns, schemas or tablespaces. For other types, the default privileges granted to PUBLIC are as follows: CONNECT and CREATE TEMP TABLE for databases; EXECUTE privilege for functions; and USAGE privilege for languages. The object owner can, of course, REVOKE both default and expressly granted privileges. (For maximum security, issue the REVOKE in the same transaction that creates the object; then there is no window in which another user can use the object.) Also, these initial default privilege settings can be changed using the ALTER DEFAULT PRIVILEGES command.

The possible privileges are:

SELECT

Allows SELECT from any column, or the specific columns listed, of the specified table, view, or sequence. Also allows the use of COPY TO. This privilege is also needed to reference existing column values in UPDATE or DELETE. For sequences, this privilege also allows the use of the `currval` function. For large objects, this privilege allows the object to be read.

INSERT

Allows INSERT of a new row into the specified table. If specific columns are listed, only those columns may be assigned to in the `INSERT` command (other columns will therefore receive default values). Also allows COPY FROM.

UPDATE

Allows UPDATE of any column, or the specific columns listed, of the specified table. (In practice, any nontrivial `UPDATE` command will require `SELECT` privilege as well, since it must reference table columns to determine which rows to update, and/or to compute new values for columns.) `SELECT ... FOR UPDATE` and `SELECT ... FOR SHARE` also require this privilege on at least one column, in addition to the `SELECT` privilege. For sequences, this privilege allows the use of the `nextval` and `setval` functions. For large objects, this privilege allows writing or truncating the object.

DELETE

Allows DELETE of a row from the specified table. (In practice, any nontrivial `DELETE` command will require `SELECT` privilege as well, since it must reference table columns to determine which rows to delete.)

TRUNCATE

Allows TRUNCATE on the specified table.

REFERENCES

To create a foreign key constraint, it is necessary to have this privilege on both the referencing and referenced columns. The privilege may be granted for all columns of a table, or just specific columns.

TRIGGER

Allows the creation of a trigger on the specified table. (See the CREATE TRIGGER statement.)

CREATE

For databases, allows new schemas to be created within the database.

For schemas, allows new objects to be created within the schema. To rename an existing object, you must own the object *and* have this privilege for the containing schema.

For tablespaces, allows tables, indexes, and temporary files to be created within the tablespace, and allows databases to be created that have the tablespace as their default tablespace. (Note that revoking this privilege will not alter the placement of existing objects.)

CONNECT

Allows the user to connect to the specified database. This privilege is checked at connection startup (in addition to checking any restrictions imposed by `pg_hba.conf`).

TEMPORARY
TEMP

Allows temporary tables to be created while using the specified database.

EXECUTE

Allows the use of the specified function and the use of any operators that are implemented on top of the function. This is the only type of privilege that is applicable to functions. (This syntax works for aggregate functions, as well.)

USAGE

For procedural languages, allows the use of the specified language for the creation of functions in that language. This is the only type of privilege that is applicable to procedural languages.

For schemas, allows access to objects contained in the specified schema (assuming that the objects' own privilege requirements are also met). Essentially this allows the grantee to "look up" objects within the schema. Without this permission, it is still possible to see the object names, e.g. by querying the system tables. Also, after revoking this permission, existing backends might have statements that have previously performed this lookup, so this is not a completely secure way to prevent object access.

For sequences, this privilege allows the use of the `currval` and `nextval` functions.

For types and domains, this privilege allow the use of the type or domain in the creation of tables, functions, and other schema objects. (Note that it does not control general "usage" of the type, such as values of the type appearing in queries. It only prevents objects from being created that depend on the type. The main purpose of the privilege is controlling which users create dependencies on a type, which could prevent the owner from changing the type later.)

For foreign-data wrappers, this privilege enables the grantee to create new servers using that foreign-data wrapper.

For servers, this privilege enables the grantee to create foreign tables using the server, and also to create, alter, or drop his own user's user mappings associated with that server.

ALL PRIVILEGES

Grant all of the available privileges at once. The `PRIVILEGES` key word is optional in PostgreSQL, though it is required by strict SQL.

The privileges required by other commands are listed on the reference page of the respective command.

GRANT on Roles

This variant of the `GRANT` command grants membership in a role to one or more other roles. Membership in a role is significant because it conveys the privileges granted to a role to each of its members.

If `WITH ADMIN OPTION` is specified, the member can in turn grant membership in the role to others, and revoke membership in the role as well. Without the admin option, ordinary users cannot do that. A role is not considered to hold `WITH ADMIN OPTION` on itself, but it may grant or revoke membership in itself from a database session where the session user matches the role. Database superusers can grant or revoke membership in any role to anyone. Roles having `CREATEROLE` privilege can grant or revoke membership in any role that is not a superuser.

Unlike the case with privileges, membership in a role cannot be granted to `PUBLIC`. Note also that this form of the command does not allow the noise word `GROUP`.

Notes

The REVOKE command is used to revoke access privileges.

Since PostgreSQL 8.1, the concepts of users and groups have been unified into a single kind of entity called a role. It is therefore no longer necessary to use the keyword `GROUP` to identify whether a grantee is a user or a group. `GROUP` is still allowed in the command, but it is a noise word.

A user may perform `SELECT`, `INSERT`, etc. on a column if he holds that privilege for either the specific column or its whole table. Granting the privilege at the table level and then revoking it for one column will not do what you might wish: the table-level grant is unaffected by a column-level operation.

When a non-owner of an object attempts to `GRANT` privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will grant only those privileges for which the user has grant options. The `GRANT ALL PRIVILEGES` forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

It should be noted that database superusers can access all objects regardless of object privilege settings. This is comparable to the rights of `root` in a Unix system. As with `root`, it's unwise to operate as a superuser except when absolutely necessary.

If a superuser chooses to issue a `GRANT` or `REVOKE` command, the command is performed as though it were issued by the owner of the affected object. In particular, privileges granted via such a command will appear to have been granted by the object owner. (For role membership, the membership appears to have been granted by the containing role itself.)

`GRANT` and `REVOKE` can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case the privileges will be recorded as having been granted by the role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can grant privileges on `t1` to `u2`, but those privileges will appear to have been granted directly by `g1`. Any other member of role `g1` could revoke them later.

If the role executing `GRANT` holds the required privileges indirectly via more than one role membership path, it is unspecified which containing role will be recorded as having done the grant. In such cases it is best practice to use `SET ROLE` to become the specific role you want to do the `GRANT` as.

Granting permission on a table does not automatically extend permissions to any sequences used by the table, including sequences tied to `SERIAL` columns. Permissions on sequences must be set separately.

Use psql's `\dp` command to obtain information about existing privileges for tables and columns. For example:

```
=> \dp mytable
                              Access privileges
 Schema |  Name   | Type  |   Access privileges   | Column access privileges
--------+---------+-------+-----------------------+--------------------------
 public | mytable | table | miriam=arwdDxt/miriam | col1:
                          : =r/miriam             :   miriam_rw=rw/miriam
                          : admin=arw/miriam
(1 row)
```

The entries shown by `\dp` are interpreted thus:

```
rolename=xxxx -- privileges granted to a role
        =xxxx -- privileges granted to PUBLIC

            r -- SELECT ("read")
            w -- UPDATE ("write")
            a -- INSERT ("append")
            d -- DELETE
            D -- TRUNCATE
            x -- REFERENCES
            t -- TRIGGER
            X -- EXECUTE
            U -- USAGE
            C -- CREATE
            c -- CONNECT
            T -- TEMPORARY
      arwdDxt -- ALL PRIVILEGES (for tables, varies for other objects)
            * -- grant option for preceding privilege

        /yyyy -- role that granted this privilege
```

The above example display would be seen by user `miriam` after creating table `mytable` and doing:

```
GRANT SELECT ON mytable TO PUBLIC;
GRANT SELECT, UPDATE, INSERT ON mytable TO admin;
GRANT SELECT (col1), UPDATE (col1) ON mytable TO miriam_rw;
```

For non-table objects there are other `\d` commands that can display their privileges.

If the "Access privileges" column is empty for a given object, it means the object has default privileges (that is, its privileges column is null). Default privileges always include all privileges for the owner, and can include some privileges for `PUBLIC` depending on the object type, as explained above. The first `GRANT` or `REVOKE` on an object will instantiate the default privileges (producing, for example, `{miriam=arwdDxt/miriam}`) and then modify them per the specified request. Similarly, entries are shown in "Column access privileges" only for columns with nondefault privileges. (Note: for this purpose, "default privileges" always means the built-in default privileges for the object's type. An object whose privileges have been affected by an `ALTER DEFAULT PRIVILEGES` command will always be shown with an explicit privilege entry that includes the effects of the `ALTER`.)

Notice that the owner's implicit grant options are not marked in the access privileges display. A `*` will appear only when grant options have been explicitly granted to someone.

Examples

Grant insert privilege to all users on table `films`:

```
GRANT INSERT ON films TO PUBLIC;
```

Grant all available privileges to user `manuel` on view `kinds`:

```
GRANT ALL PRIVILEGES ON kinds TO manuel;
```

Note that while the above will indeed grant all privileges if executed by a superuser or the owner of `kinds`, when executed by someone else it will only grant those permissions for which the someone else has grant options.

Grant membership in role `admins` to user `joe`:

```
GRANT admins TO joe;
```

Compatibility

According to the SQL standard, the `PRIVILEGES` key word in `ALL PRIVILEGES` is required. The SQL standard does not support setting the privileges on more than one object per command.

PostgreSQL allows an object owner to revoke his own ordinary privileges: for example, a table owner can make the table read-only to himself by revoking his own `INSERT`, `UPDATE`, `DELETE`, and `TRUNCATE` privileges. This is not possible according to the SQL standard. The reason is that PostgreSQL treats the owner's privileges as having been granted by the owner to himself; therefore he can revoke them too. In the SQL standard, the owner's privileges are granted by an assumed entity "_SYSTEM". Not being "_SYSTEM", the owner cannot revoke these rights.

According to the SQL standard, grant options can be granted to `PUBLIC`; PostgreSQL only supports granting grant options to roles.

The SQL standard provides for a `USAGE` privilege on other kinds of objects: character sets, collations, translations.

In the SQL standard, sequences only have a `USAGE` privilege, which controls the use of the `NEXT VALUE FOR` expression, which is equivalent to the function `nextval` in PostgreSQL. The sequence privileges `SELECT` and `UPDATE` are PostgreSQL extensions. The application of the sequence `USAGE` privilege to the `currval` function is also a PostgreSQL extension (as is the function itself).

Privileges on databases, tablespaces, schemas, and languages are PostgreSQL extensions.

See Also

REVOKE, ALTER DEFAULT PRIVILEGES

INSERT

Name

INSERT — create new rows in a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
INSERT INTO table_name [ ( column_name [, ...] ) ]
    { DEFAULT VALUES | VALUES ( { expression | DEFAULT } [, ...] ) [, ...] | query }
    [ RETURNING * | output_expression [ [ AS ] output_name ] [, ...] ]
```

Description

INSERT inserts new rows into a table. One can insert one or more rows specified by value expressions, or zero or more rows resulting from a query.

The target column names can be listed in any order. If no list of column names is given at all, the default is all the columns of the table in their declared order; or the first *N* column names, if there are only *N* columns supplied by the VALUES clause or *query*. The values supplied by the VALUES clause or *query* are associated with the explicit or implicit column list left-to-right.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is none.

If the expression for any column is not of the correct data type, automatic type conversion will be attempted.

The optional RETURNING clause causes INSERT to compute and return value(s) based on each row actually inserted. This is primarily useful for obtaining values that were supplied by defaults, such as a serial sequence number. However, any expression using the table's columns is allowed. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have INSERT privilege on a table in order to insert into it. If a column list is specified, you only need INSERT privilege on the listed columns. Use of the RETURNING clause requires SELECT privilege on all columns mentioned in RETURNING. If you use the *query* clause to insert rows from a query, you of course need to have SELECT privilege on any table or column used in the query.

Parameters

with_query

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the INSERT query. See Section 7.8 and SELECT for details.

It is possible for the *query* (SELECT statement) to also contain a WITH clause. In such a case both sets of *with_query* can be referenced within the *query*, but the second one takes precedence since it is more closely nested.

table_name

The name (optionally schema-qualified) of an existing table.

column_name

The name of a column in the table named by *table_name*. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.)

DEFAULT VALUES

All columns will be filled with their default values.

expression

An expression or value to assign to the corresponding column.

DEFAULT

The corresponding column will be filled with its default value.

query

A query (SELECT statement) that supplies the rows to be inserted. Refer to the SELECT statement for a description of the syntax.

output_expression

An expression to be computed and returned by the INSERT command after each row is inserted. The expression can use any column names of the table named by *table_name*. Write * to return all columns of the inserted row(s).

output_name

A name to use for a returned column.

Outputs

On successful completion, an INSERT command returns a command tag of the form

```
INSERT oid count
```

The *count* is the number of rows inserted. If *count* is exactly one, and the target table has OIDs, then *oid* is the OID assigned to the inserted row. Otherwise *oid* is zero.

If the INSERT command contains a RETURNING clause, the result will be similar to that of a SELECT statement containing the columns and values defined in the RETURNING list, computed over the row(s) inserted by the command.

Examples

Insert a single row into table films:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, '1971-07-13', 'Comedy', '82 minutes');
```

In this example, the len column is omitted and therefore it will have the default value:

```
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

This example uses the `DEFAULT` clause for the date columns rather than specifying a value:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes');
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama');
```

To insert a row consisting entirely of default values:

```
INSERT INTO films DEFAULT VALUES;
```

To insert multiple rows using the multirow `VALUES` syntax:

```
INSERT INTO films (code, title, did, date_prod, kind) VALUES
    ('B6717', 'Tampopo', 110, '1985-02-10', 'Comedy'),
    ('HG120', 'The Dinner Game', 140, DEFAULT, 'Comedy');
```

This example inserts some rows into table `films` from a table `tmp_films` with the same column layout as `films`:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod < '2004-05-07';
```

This example inserts into array columns:

```
-- Create an empty 3x3 gameboard for noughts-and-crosses
INSERT INTO tictactoe (game, board[1:3][1:3])
    VALUES (1, '{{" "," "," "},{" "," "," "},{" "," "," "}}');
-- The subscripts in the above example aren't really needed
INSERT INTO tictactoe (game, board)
    VALUES (2, '{{X," "," "},{" ",O," "},{" ",X," "}}');
```

Insert a single row into table `distributors`, returning the sequence number generated by the `DEFAULT` clause:

```
INSERT INTO distributors (did, dname) VALUES (DEFAULT, 'XYZ Widgets')
   RETURNING did;
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, and record the whole updated row along with current time in a log table:

```
WITH upd AS (
  UPDATE employees SET sales_count = sales_count + 1 WHERE id =
    (SELECT sales_person FROM accounts WHERE name = 'Acme Corporation')
    RETURNING *
)
INSERT INTO employees_log SELECT *, current_timestamp FROM upd;
```

Compatibility

`INSERT` conforms to the SQL standard, except that the `RETURNING` clause is a PostgreSQL extension, as is the ability to use `WITH` with `INSERT`. Also, the case in which a column name list is omitted, but not all the columns are filled from the `VALUES` clause or *`query`*, is disallowed by the standard.

Possible limitations of the *`query`* clause are documented under SELECT.

LISTEN

Name

LISTEN — listen for a notification

Synopsis

```
LISTEN channel
```

Description

LISTEN registers the current session as a listener on the notification channel named *channel*. If the current session is already registered as a listener for this notification channel, nothing is done.

Whenever the command NOTIFY *channel* is invoked, either by this session or another one connected to the same database, all the sessions currently listening on that notification channel are notified, and each will in turn notify its connected client application.

A session can be unregistered for a given notification channel with the UNLISTEN command. A session's listen registrations are automatically cleared when the session ends.

The method a client application must use to detect notification events depends on which PostgreSQL application programming interface it uses. With the libpq library, the application issues LISTEN as an ordinary SQL command, and then must periodically call the function PQnotifies to find out whether any notification events have been received. Other interfaces such as libpgtcl provide higher-level methods for handling notify events; indeed, with libpgtcl the application programmer should not even issue LISTEN or UNLISTEN directly. See the documentation for the interface you are using for more details.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

Parameters

channel

Name of a notification channel (any identifier).

Notes

LISTEN takes effect at transaction commit. If LISTEN or UNLISTEN is executed within a transaction that later rolls back, the set of notification channels being listened to is unchanged.

A transaction that has executed LISTEN cannot be prepared for two-phase commit.

Examples

Configure and execute a listen/notify sequence from psql:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
```

Compatibility

There is no `LISTEN` statement in the SQL standard.

See Also

NOTIFY, UNLISTEN

LOAD

Name

LOAD — load a shared library file

Synopsis

```
LOAD 'filename'
```

Description

This command loads a shared library file into the PostgreSQL server's address space. If the file has been loaded already, the command does nothing. Shared library files that contain C functions are automatically loaded whenever one of their functions is called. Therefore, an explicit LOAD is usually only needed to load a library that modifies the server's behavior through "hooks" rather than providing a set of functions.

The file name is specified in the same way as for shared library names in CREATE FUNCTION; in particular, one can rely on a search path and automatic addition of the system's standard shared library file name extension. See Section 35.9 for more information on this topic.

Non-superusers can only apply LOAD to library files located in `$libdir/plugins/` — the specified *filename* must begin with exactly that string. (It is the database administrator's responsibility to ensure that only "safe" libraries are installed there.)

Compatibility

LOAD is a PostgreSQL extension.

See Also

CREATE FUNCTION

LOCK

Name

LOCK — lock a table

Synopsis

```
LOCK [ TABLE ] [ ONLY ] name [ * ] [, ...] [ IN lockmode MODE ] [ NOWAIT ]

where lockmode is one of:

    ACCESS SHARE | ROW SHARE | ROW EXCLUSIVE | SHARE UPDATE EXCLUSIVE
    | SHARE | SHARE ROW EXCLUSIVE | EXCLUSIVE | ACCESS EXCLUSIVE
```

Description

`LOCK TABLE` obtains a table-level lock, waiting if necessary for any conflicting locks to be released. If `NOWAIT` is specified, `LOCK TABLE` does not wait to acquire the desired lock: if it cannot be acquired immediately, the command is aborted and an error is emitted. Once obtained, the lock is held for the remainder of the current transaction. (There is no `UNLOCK TABLE` command; locks are always released at transaction end.)

When acquiring locks automatically for commands that reference tables, PostgreSQL always uses the least restrictive lock mode possible. `LOCK TABLE` provides for cases when you might need more restrictive locking. For example, suppose an application runs a transaction at the Read Committed isolation level and needs to ensure that data in a table remains stable for the duration of the transaction. To achieve this you could obtain `SHARE` lock mode over the table before querying. This will prevent concurrent data changes and ensure subsequent reads of the table see a stable view of committed data, because `SHARE` lock mode conflicts with the `ROW EXCLUSIVE` lock acquired by writers, and your `LOCK TABLE name IN SHARE MODE` statement will wait until any concurrent holders of `ROW EXCLUSIVE` mode locks commit or roll back. Thus, once you obtain the lock, there are no uncommitted writes outstanding; furthermore none can begin until you release the lock.

To achieve a similar effect when running a transaction at the `REPEATABLE READ` or `SERIALIZABLE` isolation level, you have to execute the `LOCK TABLE` statement before executing any `SELECT` or data modification statement. A `REPEATABLE READ` or `SERIALIZABLE` transaction's view of data will be frozen when its first `SELECT` or data modification statement begins. A `LOCK TABLE` later in the transaction will still prevent concurrent writes — but it won't ensure that what the transaction reads corresponds to the latest committed values.

If a transaction of this sort is going to change the data in the table, then it should use `SHARE ROW EXCLUSIVE` lock mode instead of `SHARE` mode. This ensures that only one transaction of this type runs at a time. Without this, a deadlock is possible: two transactions might both acquire `SHARE` mode, and then be unable to also acquire `ROW EXCLUSIVE` mode to actually perform their updates. (Note that a transaction's own locks never conflict, so a transaction can acquire `ROW EXCLUSIVE` mode when it holds `SHARE` mode — but not if anyone else holds `SHARE` mode.) To avoid deadlocks, make sure all transactions acquire locks on the same objects in the same order, and if multiple lock modes are involved for a single object, then transactions should always acquire the most restrictive mode first.

More information about the lock modes and locking strategies can be found in Section 13.3.

Parameters

name

The name (optionally schema-qualified) of an existing table to lock. If ONLY is specified before the table name, only that table is locked. If ONLY is not specified, the table and all its descendant tables (if any) are locked. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

The command LOCK TABLE a, b; is equivalent to LOCK TABLE a; LOCK TABLE b;. The tables are locked one-by-one in the order specified in the LOCK TABLE command.

lockmode

The lock mode specifies which locks this lock conflicts with. Lock modes are described in Section 13.3.

If no lock mode is specified, then ACCESS EXCLUSIVE, the most restrictive mode, is used.

NOWAIT

Specifies that LOCK TABLE should not wait for any conflicting locks to be released: if the specified lock(s) cannot be acquired immediately without waiting, the transaction is aborted.

Notes

LOCK TABLE ... IN ACCESS SHARE MODE requires SELECT privileges on the target table. All other forms of LOCK require table-level UPDATE, DELETE, or TRUNCATE privileges.

LOCK TABLE is useless outside a transaction block: the lock would remain held only to the completion of the statement. Therefore PostgreSQL reports an error if LOCK is used outside a transaction block. Use BEGIN and COMMIT (or ROLLBACK) to define a transaction block.

LOCK TABLE only deals with table-level locks, and so the mode names involving ROW are all misnomers. These mode names should generally be read as indicating the intention of the user to acquire row-level locks within the locked table. Also, ROW EXCLUSIVE mode is a shareable table lock. Keep in mind that all the lock modes have identical semantics so far as LOCK TABLE is concerned, differing only in the rules about which modes conflict with which. For information on how to acquire an actual row-level lock, see Section 13.3.2 and the *The Locking Clause* in the SELECT reference documentation.

Examples

Obtain a SHARE lock on a primary key table when going to perform inserts into a foreign key table:

```
BEGIN WORK;
LOCK TABLE films IN SHARE MODE;
SELECT id FROM films
    WHERE name = 'Star Wars: Episode I - The Phantom Menace';
-- Do ROLLBACK if record was not returned
INSERT INTO films_user_comments VALUES
    (_id_, 'GREAT! I was waiting for it for so long!');
COMMIT WORK;
```

Take a `SHARE ROW EXCLUSIVE` lock on a primary key table when going to perform a delete operation:

```
BEGIN WORK;
LOCK TABLE films IN SHARE ROW EXCLUSIVE MODE;
DELETE FROM films_user_comments WHERE id IN
    (SELECT id FROM films WHERE rating < 5);
DELETE FROM films WHERE rating < 5;
COMMIT WORK;
```

Compatibility

There is no `LOCK TABLE` in the SQL standard, which instead uses `SET TRANSACTION` to specify concurrency levels on transactions. PostgreSQL supports that too; see SET TRANSACTION for details.

Except for `ACCESS SHARE`, `ACCESS EXCLUSIVE`, and `SHARE UPDATE EXCLUSIVE` lock modes, the PostgreSQL lock modes and the `LOCK TABLE` syntax are compatible with those present in Oracle.

MOVE

Name

MOVE — position a cursor

Synopsis

```
MOVE [ direction [ FROM | IN ] ] cursor_name

where direction can be empty or one of:

    NEXT
    PRIOR
    FIRST
    LAST
    ABSOLUTE count
    RELATIVE count
    count
    ALL
    FORWARD
    FORWARD count
    FORWARD ALL
    BACKWARD
    BACKWARD count
    BACKWARD ALL
```

Description

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only positions the cursor and does not return rows.

The parameters for the MOVE command are identical to those of the FETCH command; refer to FETCH for details on syntax and usage.

Outputs

On successful completion, a MOVE command returns a command tag of the form

```
MOVE count
```

The *count* is the number of rows that a FETCH command with the same parameters would have returned (possibly zero).

Examples

```
BEGIN WORK;
DECLARE liahona CURSOR FOR SELECT * FROM films;

-- Skip the first 5 rows:
```

```
MOVE FORWARD 5 IN liahona;
MOVE 5

-- Fetch the 6th row from the cursor liahona:
FETCH 1 FROM liahona;
 code  | title  | did | date_prod  |  kind  |  len
-------+--------+-----+------------+--------+-------
 P_303 | 48 Hrs | 103 | 1982-10-22 | Action | 01:37
(1 row)

-- Close the cursor liahona and end the transaction:
CLOSE liahona;
COMMIT WORK;
```

Compatibility

There is no `MOVE` statement in the SQL standard.

See Also

CLOSE, DECLARE, FETCH

NOTIFY

Name

NOTIFY — generate a notification

Synopsis

```
NOTIFY channel [ , payload ]
```

Description

The NOTIFY command sends a notification event together with an optional "payload" string to each client application that has previously executed LISTEN *channel* for the specified channel name in the current database. Notifications are visible to all users.

NOTIFY provides a simple interprocess communication mechanism for a collection of processes accessing the same PostgreSQL database. A payload string can be sent along with the notification, and higher-level mechanisms for passing structured data can be built by using tables in the database to pass additional data from notifier to listener(s).

The information passed to the client for a notification event includes the notification channel name, the notifying session's server process PID, and the payload string, which is an empty string if it has not been specified.

It is up to the database designer to define the channel names that will be used in a given database and what each one means. Commonly, the channel name is the same as the name of some table in the database, and the notify event essentially means, "I changed this table, take a look at it to see what's new". But no such association is enforced by the NOTIFY and LISTEN commands. For example, a database designer could use several different channel names to signal different sorts of changes to a single table. Alternatively, the payload string could be used to differentiate various cases.

When NOTIFY is used to signal the occurrence of changes to a particular table, a useful programming technique is to put the NOTIFY in a rule that is triggered by table updates. In this way, notification happens automatically when the table is changed, and the application programmer cannot accidentally forget to do it.

NOTIFY interacts with SQL transactions in some important ways. Firstly, if a NOTIFY is executed inside a transaction, the notify events are not delivered until and unless the transaction is committed. This is appropriate, since if the transaction is aborted, all the commands within it have had no effect, including NOTIFY. But it can be disconcerting if one is expecting the notification events to be delivered immediately. Secondly, if a listening session receives a notification signal while it is within a transaction, the notification event will not be delivered to its connected client until just after the transaction is completed (either committed or aborted). Again, the reasoning is that if a notification were delivered within a transaction that was later aborted, one would want the notification to be undone somehow — but the server cannot "take back" a notification once it has sent it to the client. So notification events are only delivered between transactions. The upshot of this is that applications using NOTIFY for real-time signaling should try to keep their transactions short.

If the same channel name is signaled multiple times from the same transaction with identical payload strings, the database server can decide to deliver a single notification only. On the other hand, notifications with distinct payload strings will always be delivered as distinct notifications. Similarly,

notifications from different transactions will never get folded into one notification. Except for dropping later instances of duplicate notifications, `NOTIFY` guarantees that notifications from the same transaction get delivered in the order they were sent. It is also guaranteed that messages from different transactions are delivered in the order in which the transactions committed.

It is common for a client that executes `NOTIFY` to be listening on the same notification channel itself. In that case it will get back a notification event, just like all the other listening sessions. Depending on the application logic, this could result in useless work, for example, reading a database table to find the same updates that that session just wrote out. It is possible to avoid such extra work by noticing whether the notifying session's server process PID (supplied in the notification event message) is the same as one's own session's PID (available from libpq). When they are the same, the notification event is one's own work bouncing back, and can be ignored.

Parameters

channel

Name of the notification channel to be signaled (any identifier).

payload

The "payload" string to be communicated along with the notification. This must be specified as a simple string literal. In the default configuration it must be shorter than 8000 bytes. (If binary data or large amounts of information need to be communicated, it's best to put it in a database table and send the key of the record.)

Notes

There is a queue that holds notifications that have been sent but not yet processed by all listening sessions. If this queue becomes full, transactions calling `NOTIFY` will fail at commit. The queue is quite large (8GB in a standard installation) and should be sufficiently sized for almost every use case. However, no cleanup can take place if a session executes `LISTEN` and then enters a transaction for a very long time. Once the queue is half full you will see warnings in the log file pointing you to the session that is preventing cleanup. In this case you should make sure that this session ends its current transaction so that cleanup can proceed.

A transaction that has executed `NOTIFY` cannot be prepared for two-phase commit.

pg_notify

To send a notification you can also use the function `pg_notify(text, text)`. The function takes the channel name as the first argument and the payload as the second. The function is much easier to use than the `NOTIFY` command if you need to work with non-constant channel names and payloads.

Examples

Configure and execute a listen/notify sequence from psql:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
```

```
NOTIFY virtual, 'This is the payload';
Asynchronous notification "virtual" with payload "This is the payload" received from ser

LISTEN foo;
SELECT pg_notify('fo' || 'o', 'pay' || 'load');
Asynchronous notification "foo" with payload "payload" received from server process with
```

Compatibility

There is no `NOTIFY` statement in the SQL standard.

See Also

LISTEN, UNLISTEN

PREPARE

Name

PREPARE — prepare a statement for execution

Synopsis

```
PREPARE name [ ( data_type [, ...] ) ] AS statement
```

Description

PREPARE creates a prepared statement. A prepared statement is a server-side object that can be used to optimize performance. When the PREPARE statement is executed, the specified statement is parsed, analyzed, and rewritten. When an EXECUTE command is subsequently issued, the prepared statement is planned and executed. This division of labor avoids repetitive parse analysis work, while allowing the execution plan to depend on the specific parameter values supplied.

Prepared statements can take parameters: values that are substituted into the statement when it is executed. When creating the prepared statement, refer to parameters by position, using $1, $2, etc. A corresponding list of parameter data types can optionally be specified. When a parameter's data type is not specified or is declared as unknown, the type is inferred from the context in which the parameter is used (if possible). When executing the statement, specify the actual values for these parameters in the EXECUTE statement. Refer to EXECUTE for more information about that.

Prepared statements only last for the duration of the current database session. When the session ends, the prepared statement is forgotten, so it must be recreated before being used again. This also means that a single prepared statement cannot be used by multiple simultaneous database clients; however, each client can create their own prepared statement to use. Prepared statements can be manually cleaned up using the DEALLOCATE command.

Prepared statements have the largest performance advantage when a single session is being used to execute a large number of similar statements. The performance difference will be particularly significant if the statements are complex to plan or rewrite, for example, if the query involves a join of many tables or requires the application of several rules. If the statement is relatively simple to plan and rewrite but relatively expensive to execute, the performance advantage of prepared statements will be less noticeable.

Parameters

name

An arbitrary name given to this particular prepared statement. It must be unique within a single session and is subsequently used to execute or deallocate a previously prepared statement.

data_type

The data type of a parameter to the prepared statement. If the data type of a particular parameter is unspecified or is specified as unknown, it will be inferred from the context in which the parameter is used. To refer to the parameters in the prepared statement itself, use $1, $2, etc.

statement

Any SELECT, INSERT, UPDATE, DELETE, or VALUES statement.

Notes

If a prepared statement is executed enough times, the server may eventually decide to save and re-use a generic plan rather than re-planning each time. This will occur immediately if the prepared statement has no parameters; otherwise it occurs only if the generic plan appears to be not much more expensive than a plan that depends on specific parameter values. Typically, a generic plan will be selected only if the query's performance is estimated to be fairly insensitive to the specific parameter values supplied.

To examine the query plan PostgreSQL is using for a prepared statement, use EXPLAIN. If a generic plan is in use, it will contain parameter symbols $n, while a custom plan will have the current actual parameter values substituted into it.

For more information on query planning and the statistics collected by PostgreSQL for that purpose, see the ANALYZE documentation.

Although the main point of a prepared statement is to avoid repeated parse analysis and planning of the statement, PostgreSQL will force re-analysis and re-planning of the statement before using it whenever database objects used in the statement have undergone definitional (DDL) changes since the previous use of the prepared statement. Also, if the value of search_path changes from one use to the next, the statement will be re-parsed using the new search_path. (This latter behavior is new as of PostgreSQL 9.3.) These rules make use of a prepared statement semantically almost equivalent to re-submitting the same query text over and over, but with a performance benefit if no object definitions are changed, especially if the best plan remains the same across uses. An example of a case where the semantic equivalence is not perfect is that if the statement refers to a table by an unqualified name, and then a new table of the same name is created in a schema appearing earlier in the search_path, no automatic re-parse will occur since no object used in the statement changed. However, if some other change forces a re-parse, the new table will be referenced in subsequent uses.

You can see all prepared statements available in the session by querying the pg_prepared_statements system view.

Examples

Create a prepared statement for an INSERT statement, and then execute it:

```
PREPARE fooplan (int, text, bool, numeric) AS
    INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Create a prepared statement for a SELECT statement, and then execute it:

```
PREPARE usrrptplan (int) AS
    SELECT * FROM users u, logs l WHERE u.usrid=$1 AND u.usrid=l.usrid
    AND l.date = $2;
EXECUTE usrrptplan(1, current_date);
```

Note that the data type of the second parameter is not specified, so it is inferred from the context in which $2 is used.

Compatibility

The SQL standard includes a `PREPARE` statement, but it is only for use in embedded SQL. This version of the `PREPARE` statement also uses a somewhat different syntax.

See Also

DEALLOCATE, EXECUTE

PREPARE TRANSACTION

Name

PREPARE TRANSACTION — prepare the current transaction for two-phase commit

Synopsis

```
PREPARE TRANSACTION transaction_id
```

Description

PREPARE TRANSACTION prepares the current transaction for two-phase commit. After this command, the transaction is no longer associated with the current session; instead, its state is fully stored on disk, and there is a very high probability that it can be committed successfully, even if a database crash occurs before the commit is requested.

Once prepared, a transaction can later be committed or rolled back with COMMIT PREPARED or ROLLBACK PREPARED, respectively. Those commands can be issued from any session, not only the one that executed the original transaction.

From the point of view of the issuing session, PREPARE TRANSACTION is not unlike a ROLLBACK command: after executing it, there is no active current transaction, and the effects of the prepared transaction are no longer visible. (The effects will become visible again if the transaction is committed.)

If the PREPARE TRANSACTION command fails for any reason, it becomes a ROLLBACK: the current transaction is canceled.

Parameters

transaction_id

An arbitrary identifier that later identifies this transaction for COMMIT PREPARED or ROLLBACK PREPARED. The identifier must be written as a string literal, and must be less than 200 bytes long. It must not be the same as the identifier used for any currently prepared transaction.

Notes

PREPARE TRANSACTION is not intended for use in applications or interactive sessions. Its purpose is to allow an external transaction manager to perform atomic global transactions across multiple databases or other transactional resources. Unless you're writing a transaction manager, you probably shouldn't be using PREPARE TRANSACTION.

This command must be used inside a transaction block. Use BEGIN to start one.

It is not currently allowed to PREPARE a transaction that has executed any operations involving temporary tables, created any cursors WITH HOLD, or executed LISTEN or UNLISTEN. Those features are too tightly tied to the current session to be useful in a transaction to be prepared.

If the transaction modified any run-time parameters with `SET` (without the `LOCAL` option), those effects persist after `PREPARE TRANSACTION`, and will not be affected by any later `COMMIT PREPARED` or `ROLLBACK PREPARED`. Thus, in this one respect `PREPARE TRANSACTION` acts more like `COMMIT` than `ROLLBACK`.

All currently available prepared transactions are listed in the `pg_prepared_xacts` system view.

Caution

It is unwise to leave transactions in the prepared state for a long time. This will interfere with the ability of `VACUUM` to reclaim storage, and in extreme cases could cause the database to shut down to prevent transaction ID wraparound (see Section 23.1.5). Keep in mind also that the transaction continues to hold whatever locks it held. The intended usage of the feature is that a prepared transaction will normally be committed or rolled back as soon as an external transaction manager has verified that other databases are also prepared to commit.

If you have not set up an external transaction manager to track prepared transactions and ensure they get closed out promptly, it is best to keep the prepared-transaction feature disabled by setting max_prepared_transactions to zero. This will prevent accidental creation of prepared transactions that might then be forgotten and eventually cause problems.

Examples

Prepare the current transaction for two-phase commit, using `foobar` as the transaction identifier:

```
PREPARE TRANSACTION 'foobar';
```

Compatibility

`PREPARE TRANSACTION` is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

COMMIT PREPARED, ROLLBACK PREPARED

REASSIGN OWNED

Name

REASSIGN OWNED — change the ownership of database objects owned by a database role

Synopsis

```
REASSIGN OWNED BY old_role [, ...] TO new_role
```

Description

REASSIGN OWNED instructs the system to change the ownership of database objects owned by one of the old_roles, to new_role.

Parameters

old_role

The name of a role. The ownership of all the objects within the current database, and of all shared objects (databases, tablespaces), owned by this role will be reassigned to *new_role*.

new_role

The name of the role that will be made the new owner of the affected objects.

Notes

REASSIGN OWNED is often used to prepare for the removal of one or more roles. Because REASSIGN OWNED does not affect objects within other databases, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.

REASSIGN OWNED requires privileges on both the source role(s) and the target role.

The DROP OWNED command is an alternative that drops all the database objects owned by one or more roles. Note also that DROP OWNED requires privileges only on the source role(s).

The REASSIGN OWNED command does not affect the privileges granted to the old_roles in objects that are not owned by them. Use DROP OWNED to revoke those privileges.

Compatibility

The REASSIGN OWNED statement is a PostgreSQL extension.

See Also

DROP OWNED, DROP ROLE, ALTER DATABASE

REFRESH MATERIALIZED VIEW

Name

REFRESH MATERIALIZED VIEW — replace the contents of a materialized view

Synopsis

```
REFRESH MATERIALIZED VIEW [ CONCURRENTLY ] name
    [ WITH [ NO ] DATA ]
```

Description

REFRESH MATERIALIZED VIEW completely replaces the contents of a materialized view. The old contents are discarded. If WITH DATA is specified (or defaults) the backing query is executed to provide the new data, and the materialized view is left in a scannable state. If WITH NO DATA is specified no new data is generated and the materialized view is left in an unscannable state.

CONCURRENTLY and WITH NO DATA may not be specified together.

Parameters

CONCURRENTLY

Refresh the materialized view without locking out concurrent selects on the materialized view. Without this option a refresh which affects a lot of rows will tend to use fewer resources and complete more quickly, but could block other connections which are trying to read from the materialized view. This option may be faster in cases where a small number of rows are affected.

This option is only allowed if there is at least one UNIQUE index on the materialized view which uses only column names and includes all rows; that is, it must not index on any expressions nor include a WHERE clause.

This option may not be used when the materialized view is not already populated.

Even with this option only one REFRESH at a time may run against any one materialized view.

name

The name (optionally schema-qualified) of the materialized view to refresh.

Notes

While the default index for future CLUSTER operations is retained, REFRESH MATERIALIZED VIEW does not order the generated rows based on this property. If you want the data to be ordered upon generation, you must use an ORDER BY clause in the backing query.

Examples

This command will replace the contents of the materialized view called `order_summary` using the query from the materialized view's definition, and leave it in a scannable state:

```
REFRESH MATERIALIZED VIEW order_summary;
```

This command will free storage associated with the materialized view `annual_statistics_basis` and leave it in an unscannable state:

```
REFRESH MATERIALIZED VIEW annual_statistics_basis WITH NO DATA;
```

Compatibility

`REFRESH MATERIALIZED VIEW` is a PostgreSQL extension.

See Also

CREATE MATERIALIZED VIEW, ALTER MATERIALIZED VIEW, DROP MATERIALIZED VIEW

REINDEX

Name

REINDEX — rebuild indexes

Synopsis

```
REINDEX { INDEX | TABLE | DATABASE | SYSTEM } name [ FORCE ]
```

Description

REINDEX rebuilds an index using the data stored in the index's table, replacing the old copy of the index. There are several scenarios in which to use REINDEX:

- An index has become corrupted, and no longer contains valid data. Although in theory this should never happen, in practice indexes can become corrupted due to software bugs or hardware failures. REINDEX provides a recovery method.
- An index has become "bloated", that is it contains many empty or nearly-empty pages. This can occur with B-tree indexes in PostgreSQL under certain uncommon access patterns. REINDEX provides a way to reduce the space consumption of the index by writing a new version of the index without the dead pages. See Section 23.2 for more information.
- You have altered a storage parameter (such as fillfactor) for an index, and wish to ensure that the change has taken full effect.
- An index build with the CONCURRENTLY option failed, leaving an "invalid" index. Such indexes are useless but it can be convenient to use REINDEX to rebuild them. Note that REINDEX will not perform a concurrent build. To build the index without interfering with production you should drop the index and reissue the CREATE INDEX CONCURRENTLY command.

Parameters

INDEX

Recreate the specified index.

TABLE

Recreate all indexes of the specified table. If the table has a secondary "TOAST" table, that is reindexed as well.

DATABASE

Recreate all indexes within the current database. Indexes on shared system catalogs are also processed. This form of REINDEX cannot be executed inside a transaction block.

`SYSTEM`

Recreate all indexes on system catalogs within the current database. Indexes on shared system catalogs are included. Indexes on user tables are not processed. This form of `REINDEX` cannot be executed inside a transaction block.

`name`

The name of the specific index, table, or database to be reindexed. Index and table names can be schema-qualified. Presently, `REINDEX DATABASE` and `REINDEX SYSTEM` can only reindex the current database, so their parameter must match the current database's name.

`FORCE`

This is an obsolete option; it is ignored if specified.

Notes

If you suspect corruption of an index on a user table, you can simply rebuild that index, or all indexes on the table, using `REINDEX INDEX` or `REINDEX TABLE`.

Things are more difficult if you need to recover from corruption of an index on a system table. In this case it's important for the system to not have used any of the suspect indexes itself. (Indeed, in this sort of scenario you might find that server processes are crashing immediately at start-up, due to reliance on the corrupted indexes.) To recover safely, the server must be started with the `-P` option, which prevents it from using indexes for system catalog lookups.

One way to do this is to shut down the server and start a single-user PostgreSQL server with the `-P` option included on its command line. Then, `REINDEX DATABASE`, `REINDEX SYSTEM`, `REINDEX TABLE`, or `REINDEX INDEX` can be issued, depending on how much you want to reconstruct. If in doubt, use `REINDEX SYSTEM` to select reconstruction of all system indexes in the database. Then quit the single-user server session and restart the regular server. See the postgres reference page for more information about how to interact with the single-user server interface.

Alternatively, a regular server session can be started with `-P` included in its command line options. The method for doing this varies across clients, but in all libpq-based clients, it is possible to set the `PGOPTIONS` environment variable to `-P` before starting the client. Note that while this method does not require locking out other clients, it might still be wise to prevent other users from connecting to the damaged database until repairs have been completed.

`REINDEX` is similar to a drop and recreate of the index in that the index contents are rebuilt from scratch. However, the locking considerations are rather different. `REINDEX` locks out writes but not reads of the index's parent table. It also takes an exclusive lock on the specific index being processed, which will block reads that attempt to use that index. In contrast, `DROP INDEX` momentarily takes an exclusive lock on the parent table, blocking both writes and reads. The subsequent `CREATE INDEX` locks out writes but not reads; since the index is not there, no read will attempt to use it, meaning that there will be no blocking but reads might be forced into expensive sequential scans.

Reindexing a single index or table requires being the owner of that index or table. Reindexing a database requires being the owner of the database (note that the owner can therefore rebuild indexes of tables owned by other users). Of course, superusers can always reindex anything.

Examples

Rebuild a single index:

```
REINDEX INDEX my_index;
```

Rebuild all the indexes on the table `my_table`:

```
REINDEX TABLE my_table;
```

Rebuild all indexes in a particular database, without trusting the system indexes to be valid already:

```
$ export PGOPTIONS="-P"
$ psql broken_db
...
broken_db=> REINDEX DATABASE broken_db;
broken_db=> \q
```

Compatibility

There is no `REINDEX` command in the SQL standard.

RELEASE SAVEPOINT

Name

`RELEASE SAVEPOINT` — destroy a previously defined savepoint

Synopsis

```
RELEASE [ SAVEPOINT ] savepoint_name
```

Description

`RELEASE SAVEPOINT` destroys a savepoint previously defined in the current transaction.

Destroying a savepoint makes it unavailable as a rollback point, but it has no other user visible behavior. It does not undo the effects of commands executed after the savepoint was established. (To do that, see ROLLBACK TO SAVEPOINT.) Destroying a savepoint when it is no longer needed allows the system to reclaim some resources earlier than transaction end.

`RELEASE SAVEPOINT` also destroys all savepoints that were established after the named savepoint was established.

Parameters

savepoint_name

The name of the savepoint to destroy.

Notes

Specifying a savepoint name that was not previously defined is an error.

It is not possible to release a savepoint when the transaction is in an aborted state.

If multiple savepoints have the same name, only the one that was most recently defined is released.

Examples

To establish and later destroy a savepoint:

```
BEGIN;
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
COMMIT;
```

The above transaction will insert both 3 and 4.

Compatibility

This command conforms to the SQL standard. The standard specifies that the key word `SAVEPOINT` is mandatory, but PostgreSQL allows it to be omitted.

See Also

BEGIN, COMMIT, ROLLBACK, ROLLBACK TO SAVEPOINT, SAVEPOINT

RESET

Name

RESET — restore the value of a run-time parameter to the default value

Synopsis

```
RESET configuration_parameter
RESET ALL
```

Description

RESET restores run-time parameters to their default values. RESET is an alternative spelling for

```
SET configuration_parameter TO DEFAULT
```

Refer to SET for details.

The default value is defined as the value that the parameter would have had, if no SET had ever been issued for it in the current session. The actual source of this value might be a compiled-in default, the configuration file, command-line options, or per-database or per-user default settings. This is subtly different from defining it as "the value that the parameter had at session start", because if the value came from the configuration file, it will be reset to whatever is specified by the configuration file now. See Chapter 18 for details.

The transactional behavior of RESET is the same as SET: its effects will be undone by transaction rollback.

Parameters

configuration_parameter

Name of a settable run-time parameter. Available parameters are documented in Chapter 18 and on the SET reference page.

ALL

Resets all settable run-time parameters to default values.

Examples

Set the timezone configuration variable to its default value:

```
RESET timezone;
```

Compatibility

`RESET` is a PostgreSQL extension.

See Also

SET, SHOW

REVOKE

Name

REVOKE — remove access privileges

Synopsis

```
REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | DELETE | TRUNCATE | REFERENCES | TRIGGER }
    [, ...] | ALL [ PRIVILEGES ] }
    ON { [ TABLE ] table_name [, ...]
         | ALL TABLES IN SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { SELECT | INSERT | UPDATE | REFERENCES } ( column_name [, ...] )
    [, ...] | ALL [ PRIVILEGES ] ( column_name [, ...] ) }
    ON [ TABLE ] table_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { USAGE | SELECT | UPDATE }
    [, ...] | ALL [ PRIVILEGES ] }
    ON { SEQUENCE sequence_name [, ...]
         | ALL SEQUENCES IN SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { CREATE | CONNECT | TEMPORARY | TEMP } [, ...] | ALL [ PRIVILEGES ] }
    ON DATABASE database_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON DOMAIN domain_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN DATA WRAPPER fdw_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON FOREIGN SERVER server_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]
```

```
REVOKE [ GRANT OPTION FOR ]
    { EXECUTE | ALL [ PRIVILEGES ] }
    ON { FUNCTION function_name ( [ [ argmode ] [ arg_name ] arg_type [, ...] ] ) [, ...]
         | ALL FUNCTIONS IN SCHEMA schema_name [, ...] }
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON LANGUAGE lang_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { SELECT | UPDATE } [, ...] | ALL [ PRIVILEGES ] }
    ON LARGE OBJECT loid [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { { CREATE | USAGE } [, ...] | ALL [ PRIVILEGES ] }
    ON SCHEMA schema_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { CREATE | ALL [ PRIVILEGES ] }
    ON TABLESPACE tablespace_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ GRANT OPTION FOR ]
    { USAGE | ALL [ PRIVILEGES ] }
    ON TYPE type_name [, ...]
    FROM { [ GROUP ] role_name | PUBLIC } [, ...]
    [ CASCADE | RESTRICT ]

REVOKE [ ADMIN OPTION FOR ]
    role_name [, ...] FROM role_name [, ...]
    [ CASCADE | RESTRICT ]
```

Description

The REVOKE command revokes previously granted privileges from one or more roles. The key word PUBLIC refers to the implicitly defined group of all roles.

See the description of the GRANT command for the meaning of the privilege types.

Note that any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC. Thus, for example, revoking SELECT privilege from PUBLIC does not necessarily mean that all roles have lost SELECT privilege on the object: those who have it granted directly or via another role will still have it. Similarly, revoking SELECT from a user might not prevent that user from using SELECT if PUBLIC or another membership role still has SELECT rights.

If `GRANT OPTION FOR` is specified, only the grant option for the privilege is revoked, not the privilege itself. Otherwise, both the privilege and the grant option are revoked.

If a user holds a privilege with grant option and has granted it to other users then the privileges held by those other users are called dependent privileges. If the privilege or the grant option held by the first user is being revoked and dependent privileges exist, those dependent privileges are also revoked if `CASCADE` is specified; if it is not, the revoke action will fail. This recursive revocation only affects privileges that were granted through a chain of users that is traceable to the user that is the subject of this `REVOKE` command. Thus, the affected users might effectively keep the privilege if it was also granted through other users.

When revoking privileges on a table, the corresponding column privileges (if any) are automatically revoked on each column of the table, as well. On the other hand, if a role has been granted privileges on a table, then revoking the same privileges from individual columns will have no effect.

When revoking membership in a role, `GRANT OPTION` is instead called `ADMIN OPTION`, but the behavior is similar. Note also that this form of the command does not allow the noise word `GROUP`.

Notes

Use psql's `\dp` command to display the privileges granted on existing tables and columns. See GRANT for information about the format. For non-table objects there are other `\d` commands that can display their privileges.

A user can only revoke privileges that were granted directly by that user. If, for example, user A has granted a privilege with grant option to user B, and user B has in turned granted it to user C, then user A cannot revoke the privilege directly from C. Instead, user A could revoke the grant option from user B and use the `CASCADE` option so that the privilege is in turn revoked from user C. For another example, if both A and B have granted the same privilege to C, A can revoke his own grant but not B's grant, so C will still effectively have the privilege.

When a non-owner of an object attempts to `REVOKE` privileges on the object, the command will fail outright if the user has no privileges whatsoever on the object. As long as some privilege is available, the command will proceed, but it will revoke only those privileges for which the user has grant options. The `REVOKE ALL PRIVILEGES` forms will issue a warning message if no grant options are held, while the other forms will issue a warning if grant options for any of the privileges specifically named in the command are not held. (In principle these statements apply to the object owner as well, but since the owner is always treated as holding all grant options, the cases can never occur.)

If a superuser chooses to issue a `GRANT` or `REVOKE` command, the command is performed as though it were issued by the owner of the affected object. Since all privileges ultimately come from the object owner (possibly indirectly via chains of grant options), it is possible for a superuser to revoke all privileges, but this might require use of `CASCADE` as stated above.

`REVOKE` can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges `WITH GRANT OPTION` on the object. In this case the command is performed as though it were issued by the containing role that actually owns the object or holds the privileges `WITH GRANT OPTION`. For example, if table `t1` is owned by role `g1`, of which role `u1` is a member, then `u1` can revoke privileges on `t1` that are recorded as being granted by `g1`. This would include grants made by `u1` as well as by other members of role `g1`.

If the role executing `REVOKE` holds privileges indirectly via more than one role membership path, it is unspecified which containing role will be used to perform the command. In such cases it is best practice to use `SET ROLE` to become the specific role you want to do the `REVOKE` as. Failure to do so might lead to revoking privileges other than the ones you intended, or not revoking anything at all.

Examples

Revoke insert privilege for the public on table `films`:

```
REVOKE INSERT ON films FROM PUBLIC;
```

Revoke all privileges from user `manuel` on view `kinds`:

```
REVOKE ALL PRIVILEGES ON kinds FROM manuel;
```

Note that this actually means “revoke all privileges that I granted”.

Revoke membership in role `admins` from user `joe`:

```
REVOKE admins FROM joe;
```

Compatibility

The compatibility notes of the GRANT command apply analogously to `REVOKE`. The keyword `RESTRICT` or `CASCADE` is required according to the standard, but PostgreSQL assumes `RESTRICT` by default.

See Also

GRANT

ROLLBACK

Name

ROLLBACK — abort the current transaction

Synopsis

```
ROLLBACK [ WORK | TRANSACTION ]
```

Description

ROLLBACK rolls back the current transaction and causes all the updates made by the transaction to be discarded.

Parameters

WORK
TRANSACTION

Optional key words. They have no effect.

Notes

Use COMMIT to successfully terminate a transaction.

Issuing ROLLBACK outside of a transaction block emits a warning and otherwise has no effect.

Examples

To abort all changes:

```
ROLLBACK;
```

Compatibility

The SQL standard only specifies the two forms ROLLBACK and ROLLBACK WORK. Otherwise, this command is fully conforming.

See Also

BEGIN, COMMIT, ROLLBACK TO SAVEPOINT

ROLLBACK PREPARED

Name

ROLLBACK PREPARED — cancel a transaction that was earlier prepared for two-phase commit

Synopsis

```
ROLLBACK PREPARED transaction_id
```

Description

ROLLBACK PREPARED rolls back a transaction that is in prepared state.

Parameters

transaction_id

The transaction identifier of the transaction that is to be rolled back.

Notes

To roll back a prepared transaction, you must be either the same user that executed the transaction originally, or a superuser. But you do not have to be in the same session that executed the transaction.

This command cannot be executed inside a transaction block. The prepared transaction is rolled back immediately.

All currently available prepared transactions are listed in the pg_prepared_xacts system view.

Examples

Roll back the transaction identified by the transaction identifier foobar:

```
ROLLBACK PREPARED 'foobar';
```

Compatibility

ROLLBACK PREPARED is a PostgreSQL extension. It is intended for use by external transaction management systems, some of which are covered by standards (such as X/Open XA), but the SQL side of those systems is not standardized.

See Also

PREPARE TRANSACTION, COMMIT PREPARED

ROLLBACK TO SAVEPOINT

Name

ROLLBACK TO SAVEPOINT — roll back to a savepoint

Synopsis

```
ROLLBACK [ WORK | TRANSACTION ] TO [ SAVEPOINT ] savepoint_name
```

Description

Roll back all commands that were executed after the savepoint was established. The savepoint remains valid and can be rolled back to again later, if needed.

ROLLBACK TO SAVEPOINT implicitly destroys all savepoints that were established after the named savepoint.

Parameters

savepoint_name

The savepoint to roll back to.

Notes

Use RELEASE SAVEPOINT to destroy a savepoint without discarding the effects of commands executed after it was established.

Specifying a savepoint name that has not been established is an error.

Cursors have somewhat non-transactional behavior with respect to savepoints. Any cursor that is opened inside a savepoint will be closed when the savepoint is rolled back. If a previously opened cursor is affected by a FETCH or MOVE command inside a savepoint that is later rolled back, the cursor remains at the position that FETCH left it pointing to (that is, the cursor motion caused by FETCH is not rolled back). Closing a cursor is not undone by rolling back, either. However, other side-effects caused by the cursor's query (such as side-effects of volatile functions called by the query) *are* rolled back if they occur during a savepoint that is later rolled back. A cursor whose execution causes a transaction to abort is put in a cannot-execute state, so while the transaction can be restored using ROLLBACK TO SAVEPOINT, the cursor can no longer be used.

Examples

To undo the effects of the commands executed after my_savepoint was established:

```
ROLLBACK TO SAVEPOINT my_savepoint;
```

Cursor positions are not affected by savepoint rollback:

```
BEGIN;

DECLARE foo CURSOR FOR SELECT 1 UNION SELECT 2;

SAVEPOINT foo;

FETCH 1 FROM foo;
 ?column?
----------
        1

ROLLBACK TO SAVEPOINT foo;

FETCH 1 FROM foo;
 ?column?
----------
        2

COMMIT;
```

Compatibility

The SQL standard specifies that the key word `SAVEPOINT` is mandatory, but PostgreSQL and Oracle allow it to be omitted. SQL allows only `WORK`, not `TRANSACTION`, as a noise word after `ROLLBACK`. Also, SQL has an optional clause `AND [ NO ] CHAIN` which is not currently supported by PostgreSQL. Otherwise, this command conforms to the SQL standard.

See Also

BEGIN, COMMIT, RELEASE SAVEPOINT, ROLLBACK, SAVEPOINT

SAVEPOINT

Name

SAVEPOINT — define a new savepoint within the current transaction

Synopsis

```
SAVEPOINT savepoint_name
```

Description

SAVEPOINT establishes a new savepoint within the current transaction.

A savepoint is a special mark inside a transaction that allows all commands that are executed after it was established to be rolled back, restoring the transaction state to what it was at the time of the savepoint.

Parameters

savepoint_name

The name to give to the new savepoint.

Notes

Use ROLLBACK TO SAVEPOINT to rollback to a savepoint. Use RELEASE SAVEPOINT to destroy a savepoint, keeping the effects of commands executed after it was established.

Savepoints can only be established when inside a transaction block. There can be multiple savepoints defined within a transaction.

Examples

To establish a savepoint and later undo the effects of all commands executed after it was established:

```
BEGIN;
    INSERT INTO table1 VALUES (1);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (2);
    ROLLBACK TO SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (3);
COMMIT;
```

The above transaction will insert the values 1 and 3, but not 2.

To establish and later destroy a savepoint:

```
BEGIN;
```

```
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
COMMIT;
```

The above transaction will insert both 3 and 4.

Compatibility

SQL requires a savepoint to be destroyed automatically when another savepoint with the same name is established. In PostgreSQL, the old savepoint is kept, though only the more recent one will be used when rolling back or releasing. (Releasing the newer savepoint with `RELEASE SAVEPOINT` will cause the older one to again become accessible to `ROLLBACK TO SAVEPOINT` and `RELEASE SAVEPOINT`.) Otherwise, `SAVEPOINT` is fully SQL conforming.

See Also

BEGIN, COMMIT, RELEASE SAVEPOINT, ROLLBACK, ROLLBACK TO SAVEPOINT

SECURITY LABEL

Name

SECURITY LABEL — define or change a security label applied to an object

Synopsis

```
SECURITY LABEL [ FOR provider ] ON
{
  TABLE object_name |
  COLUMN table_name.column_name |
  AGGREGATE aggregate_name ( aggregate_signature ) |
  DATABASE object_name |
  DOMAIN object_name |
  EVENT TRIGGER object_name |
  FOREIGN TABLE object_name
  FUNCTION function_name ( [ [ argmode ] [ argname ] argtype [, ...] ] ) |
  LARGE OBJECT large_object_oid |
  MATERIALIZED VIEW object_name |
  [ PROCEDURAL ] LANGUAGE object_name |
  ROLE object_name |
  SCHEMA object_name |
  SEQUENCE object_name |
  TABLESPACE object_name |
  TYPE object_name |
  VIEW object_name
} IS 'label'

where aggregate_signature is:

* |
[ argmode ] [ argname ] argtype [ , ... ] |
[ [ argmode ] [ argname ] argtype [ , ... ] ] ORDER BY [ argmode ] [ argname ] argtype [ , .
```

Description

SECURITY LABEL applies a security label to a database object. An arbitrary number of security labels, one per label provider, can be associated with a given database object. Label providers are loadable modules which register themselves by using the function register_label_provider.

> **Note:** register_label_provider is not an SQL function; it can only be called from C code loaded into the backend.

The label provider determines whether a given label is valid and whether it is permissible to assign that label to a given object. The meaning of a given label is likewise at the discretion of the label provider. PostgreSQL places no restrictions on whether or how a label provider must interpret security labels; it merely provides a mechanism for storing them. In practice, this facility is intended to allow integration with label-based mandatory access control (MAC) systems such as SE-Linux. Such systems make all

access control decisions based on object labels, rather than traditional discretionary access control (DAC) concepts such as users and groups.

Parameters

object_name
table_name.column_name
aggregate_name
function_name

The name of the object to be labeled. Names of tables, aggregates, domains, foreign tables, functions, sequences, types, and views can be schema-qualified.

provider

The name of the provider with which this label is to be associated. The named provider must be loaded and must consent to the proposed labeling operation. If exactly one provider is loaded, the provider name may be omitted for brevity.

argmode

The mode of a function or aggregate argument: `IN`, `OUT`, `INOUT`, or `VARIADIC`. If omitted, the default is `IN`. Note that `SECURITY LABEL` does not actually pay any attention to `OUT` arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the `IN`, `INOUT`, and `VARIADIC` arguments.

argname

The name of a function or aggregate argument. Note that `SECURITY LABEL` does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype

The data type of a function or aggregate argument.

large_object_oid

The OID of the large object.

`PROCEDURAL`

This is a noise word.

label

The new security label, written as a string literal; or `NULL` to drop the security label.

Examples

The following example shows how the security label of a table might be changed.

```
SECURITY LABEL FOR selinux ON TABLE mytable IS 'system_u:object_r:sepgsql_table_t:s0';
```

Compatibility

There is no `SECURITY LABEL` command in the SQL standard.

See Also

sepgsql, dummy_seclabel

SELECT

Name

SELECT, TABLE, WITH — retrieve rows from a table or view

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    [ * | expression [ [ AS ] output_name ] [, ...] ]
    [ FROM from_item [, ...] ]
    [ WHERE condition ]
    [ GROUP BY expression [, ...] ]
    [ HAVING condition [, ...] ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT } [ ALL | DISTINCT ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ..
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
    [ FOR { UPDATE | NO KEY UPDATE | SHARE | KEY SHARE } [ OF table_name [, ...] ] [ NOWA

where from_item can be one of:

    [ ONLY ] table_name [ * ] [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    [ LATERAL ] ( select ) [ AS ] alias [ ( column_alias [, ...] ) ]
    with_query_name [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] )
                [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    [ LATERAL ] function_name ( [ argument [, ...] ] ) [ AS ] alias ( column_definition [, .
    [ LATERAL ] function_name ( [ argument [, ...] ] ) AS ( column_definition [, ...] )
    [ LATERAL ] ROWS FROM( function_name ( [ argument [, ...] ] ) [ AS ( column_definition [
                [ WITH ORDINALITY ] [ [ AS ] alias [ ( column_alias [, ...] ) ] ]
    from_item [ NATURAL ] join_type from_item [ ON join_condition | USING ( join_column [, ..

and with_query is:

    with_query_name [ ( column_name [, ...] ) ] AS ( select | values | insert | update | delet

TABLE [ ONLY ] table_name [ * ]
```

Description

SELECT retrieves rows from zero or more tables. The general processing of SELECT is as follows:

1. All queries in the WITH list are computed. These effectively serve as temporary tables that can be referenced in the FROM list. A WITH query that is referenced more than once in FROM is computed only once. (See *WITH Clause* below.)

2. All elements in the `FROM` list are computed. (Each element in the `FROM` list is a real or virtual table.) If more than one element is specified in the `FROM` list, they are cross-joined together. (See *FROM Clause* below.)
3. If the `WHERE` clause is specified, all rows that do not satisfy the condition are eliminated from the output. (See *WHERE Clause* below.)
4. If the `GROUP BY` clause is specified, or if there are aggregate function calls, the output is combined into groups of rows that match on one or more values, and the results of aggregate functions are computed. If the `HAVING` clause is present, it eliminates groups that do not satisfy the given condition. (See *GROUP BY Clause* and *HAVING Clause* below.)
5. The actual output rows are computed using the `SELECT` output expressions for each selected row or row group. (See *SELECT List* below.)
6. `SELECT DISTINCT` eliminates duplicate rows from the result. `SELECT DISTINCT ON` eliminates rows that match on all the specified expressions. `SELECT ALL` (the default) will return all candidate rows, including duplicates. (See *DISTINCT Clause* below.)
7. Using the operators `UNION`, `INTERSECT`, and `EXCEPT`, the output of more than one `SELECT` statement can be combined to form a single result set. The `UNION` operator returns all rows that are in one or both of the result sets. The `INTERSECT` operator returns all rows that are strictly in both result sets. The `EXCEPT` operator returns the rows that are in the first result set but not in the second. In all three cases, duplicate rows are eliminated unless `ALL` is specified. The noise word `DISTINCT` can be added to explicitly specify eliminating duplicate rows. Notice that `DISTINCT` is the default behavior here, even though `ALL` is the default for `SELECT` itself. (See *UNION Clause*, *INTERSECT Clause*, and *EXCEPT Clause* below.)
8. If the `ORDER BY` clause is specified, the returned rows are sorted in the specified order. If `ORDER BY` is not given, the rows are returned in whatever order the system finds fastest to produce. (See *ORDER BY Clause* below.)
9. If the `LIMIT` (or `FETCH FIRST`) or `OFFSET` clause is specified, the `SELECT` statement only returns a subset of the result rows. (See *LIMIT Clause* below.)
10. If `FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE` or `FOR KEY SHARE` is specified, the `SELECT` statement locks the selected rows against concurrent updates. (See *The Locking Clause* below.)

You must have `SELECT` privilege on each column used in a `SELECT` command. The use of `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` or `FOR KEY SHARE` requires `UPDATE` privilege as well (for at least one column of each table so selected).

Parameters

`WITH` Clause

The `WITH` clause allows you to specify one or more subqueries that can be referenced by name in the primary query. The subqueries effectively act as temporary tables or views for the duration of the primary query. Each subquery can be a `SELECT`, `TABLE`, `VALUES`, `INSERT`, `UPDATE` or `DELETE` statement. When writing a data-modifying statement (`INSERT`, `UPDATE` or `DELETE`) in `WITH`, it is usual to include a `RETURNING` clause. It is the output of `RETURNING`, *not* the underlying table that the statement modifies, that forms the temporary table that is read by the primary query. If `RETURNING` is

omitted, the statement is still executed, but it produces no output so it cannot be referenced as a table by the primary query.

A name (without schema qualification) must be specified for each WITH query. Optionally, a list of column names can be specified; if this is omitted, the column names are inferred from the subquery.

If RECURSIVE is specified, it allows a SELECT subquery to reference itself by name. Such a subquery must have the form

```
non_recursive_term UNION [ ALL | DISTINCT ] recursive_term
```

where the recursive self-reference must appear on the right-hand side of the UNION. Only one recursive self-reference is permitted per query. Recursive data-modifying statements are not supported, but you can use the results of a recursive SELECT query in a data-modifying statement. See Section 7.8 for an example.

Another effect of RECURSIVE is that WITH queries need not be ordered: a query can reference another one that is later in the list. (However, circular references, or mutual recursion, are not implemented.) Without RECURSIVE, WITH queries can only reference sibling WITH queries that are earlier in the WITH list.

A key property of WITH queries is that they are evaluated only once per execution of the primary query, even if the primary query refers to them more than once. In particular, data-modifying statements are guaranteed to be executed once and only once, regardless of whether the primary query reads all or any of their output.

The primary query and the WITH queries are all (notionally) executed at the same time. This implies that the effects of a data-modifying statement in WITH cannot be seen from other parts of the query, other than by reading its RETURNING output. If two such data-modifying statements attempt to modify the same row, the results are unspecified.

See Section 7.8 for additional information.

FROM Clause

The FROM clause specifies one or more source tables for the SELECT. If multiple sources are specified, the result is the Cartesian product (cross join) of all the sources. But usually qualification conditions are added (via WHERE) to restrict the returned rows to a small subset of the Cartesian product.

The FROM clause can contain the following elements:

table_name

The name (optionally schema-qualified) of an existing table or view. If ONLY is specified before the table name, only that table is scanned. If ONLY is not specified, the table and all its descendant tables (if any) are scanned. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the FROM item containing the alias. An alias is used for brevity or to eliminate ambiguity for self-joins (where the same table is scanned multiple times). When an alias is provided, it completely hides the actual name of the table or function; for example given FROM foo AS f, the remainder of the SELECT must refer to this FROM item as f not foo. If an alias is written, a column alias list can also be written to provide substitute names for one or more columns of the table.

select

A sub-SELECT can appear in the FROM clause. This acts as though its output were created as a temporary table for the duration of this single SELECT command. Note that the sub-SELECT must be surrounded by parentheses, and an alias *must* be provided for it. A VALUES command can also be used here.

with_query_name

A WITH query is referenced by writing its name, just as though the query's name were a table name. (In fact, the WITH query hides any real table of the same name for the purposes of the primary query. If necessary, you can refer to a real table of the same name by schema-qualifying the table's name.) An alias can be provided in the same way as for a table.

function_name

Function calls can appear in the FROM clause. (This is especially useful for functions that return result sets, but any function can be used.) This acts as though the function's output were created as a temporary table for the duration of this single SELECT command. When the optional WITH ORDINALITY clause is added to the function call, a new column is appended after all the function's output columns with numbering for each row.

An alias can be provided in the same way as for a table. If an alias is written, a column alias list can also be written to provide substitute names for one or more attributes of the function's composite return type, including the column added by ORDINALITY if present.

Multiple function calls can be combined into a single FROM-clause item by surrounding them with ROWS FROM(...). The output of such an item is the concatenation of the first row from each function, then the second row from each function, etc. If some of the functions produce fewer rows than others, NULLs are substituted for the missing data, so that the total number of rows returned is always the same as for the function that produced the most rows.

If the function has been defined as returning the record data type, then an alias or the key word AS must be present, followed by a column definition list in the form (*column_name data_type* [, ...]). The column definition list must match the actual number and types of columns returned by the function.

When using the ROWS FROM(...) syntax, if one of the functions requires a column definition list, it's preferred to put the column definition list after the function call inside ROWS FROM(...). A column definition list can be placed after the ROWS FROM(...) construct only if there's just a single function and no WITH ORDINALITY clause.

To use ORDINALITY together with a column definition list, you must use the ROWS FROM(...) syntax and put the column definition list inside ROWS FROM(...).

join_type

One of

- [INNER] JOIN
- LEFT [OUTER] JOIN
- RIGHT [OUTER] JOIN
- FULL [OUTER] JOIN
- CROSS JOIN

For the INNER and OUTER join types, a join condition must be specified, namely exactly one of NATURAL, ON *join_condition*, or USING (*join_column* [, ...]). See below for the meaning. For CROSS JOIN, none of these clauses can appear.

A JOIN clause combines two FROM items, which for convenience we will refer to as "tables", though in reality they can be any type of FROM item. Use parentheses if necessary to determine the order of nesting. In the absence of parentheses, JOINs nest left-to-right. In any case JOIN binds more tightly than the commas separating FROM-list items.

CROSS JOIN and INNER JOIN produce a simple Cartesian product, the same result as you get from listing the two tables at the top level of FROM, but restricted by the join condition (if any). CROSS JOIN is equivalent to INNER JOIN ON (TRUE), that is, no rows are removed by qualification. These join types are just a notational convenience, since they do nothing you couldn't do with plain FROM and WHERE.

LEFT OUTER JOIN returns all rows in the qualified Cartesian product (i.e., all combined rows that pass its join condition), plus one copy of each row in the left-hand table for which there was no right-hand row that passed the join condition. This left-hand row is extended to the full width of the joined table by inserting null values for the right-hand columns. Note that only the JOIN clause's own condition is considered while deciding which rows have matches. Outer conditions are applied afterwards.

Conversely, RIGHT OUTER JOIN returns all the joined rows, plus one row for each unmatched right-hand row (extended with nulls on the left). This is just a notational convenience, since you could convert it to a LEFT OUTER JOIN by switching the left and right tables.

FULL OUTER JOIN returns all the joined rows, plus one row for each unmatched left-hand row (extended with nulls on the right), plus one row for each unmatched right-hand row (extended with nulls on the left).

ON *join_condition*

join_condition is an expression resulting in a value of type boolean (similar to a WHERE clause) that specifies which rows in a join are considered to match.

USING (*join_column* [, ...])

A clause of the form USING (a, b, ...) is shorthand for ON left_table.a = right_table.a AND left_table.b = right_table.b .... Also, USING implies that only one of each pair of equivalent columns will be included in the join output, not both.

NATURAL

NATURAL is shorthand for a USING list that mentions all columns in the two tables that have the same names.

LATERAL

The LATERAL key word can precede a sub-SELECT FROM item. This allows the sub-SELECT to refer to columns of FROM items that appear before it in the FROM list. (Without LATERAL, each sub-SELECT is evaluated independently and so cannot cross-reference any other FROM item.)

LATERAL can also precede a function-call FROM item, but in this case it is a noise word, because the function expression can refer to earlier FROM items in any case.

A LATERAL item can appear at top level in the FROM list, or within a JOIN tree. In the latter case it can also refer to any items that are on the left-hand side of a JOIN that it is on the right-hand side of.

When a FROM item contains LATERAL cross-references, evaluation proceeds as follows: for each row of the FROM item providing the cross-referenced column(s), or set of rows of multiple FROM items providing the columns, the LATERAL item is evaluated using that row or row set's values of the columns. The resulting row(s) are joined as usual with the rows they were computed from. This is repeated for each row or set of rows from the column source table(s).

The column source table(s) must be `INNER` or `LEFT` joined to the `LATERAL` item, else there would not be a well-defined set of rows from which to compute each set of rows for the `LATERAL` item. Thus, although a construct such as *X* `RIGHT JOIN LATERAL` *Y* is syntactically valid, it is not actually allowed for *Y* to reference *X*.

`WHERE` Clause

The optional `WHERE` clause has the general form

```
WHERE condition
```

where *condition* is any expression that evaluates to a result of type `boolean`. Any row that does not satisfy this condition will be eliminated from the output. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

`GROUP BY` Clause

The optional `GROUP BY` clause has the general form

```
GROUP BY expression [, ...]
```

`GROUP BY` will condense into a single row all selected rows that share the same values for the grouped expressions. *expression* can be an input column name, or the name or ordinal number of an output column (`SELECT` list item), or an arbitrary expression formed from input-column values. In case of ambiguity, a `GROUP BY` name will be interpreted as an input-column name rather than an output column name.

Aggregate functions, if any are used, are computed across all rows making up each group, producing a separate value for each group. (If there are aggregate functions but no `GROUP BY` clause, the query is treated as having a single group comprising all the selected rows.) The set of rows fed to each aggregate function can be further filtered by attaching a `FILTER` clause to the aggregate function call; see Section 4.2.7 for more information. When a `FILTER` clause is present, only those rows matching it are included in the input to that aggregate function.

When `GROUP BY` is present, or any aggregate functions are present, it is not valid for the `SELECT` list expressions to refer to ungrouped columns except within aggregate functions or when the ungrouped column is functionally dependent on the grouped columns, since there would otherwise be more than one possible value to return for an ungrouped column. A functional dependency exists if the grouped columns (or a subset thereof) are the primary key of the table containing the ungrouped column.

Keep in mind that all aggregate functions are evaluated before evaluating any "scalar" expressions in the `HAVING` clause or `SELECT` list. This means that, for example, a `CASE` expression cannot be used to skip evaluation of an aggregate function; see Section 4.2.14.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `GROUP BY`.

`HAVING` Clause

The optional `HAVING` clause has the general form

```
HAVING condition
```

where *`condition`* is the same as specified for the `WHERE` clause.

`HAVING` eliminates group rows that do not satisfy the condition. `HAVING` is different from `WHERE`: `WHERE` filters individual rows before the application of `GROUP BY`, while `HAVING` filters group rows created by `GROUP BY`. Each column referenced in *`condition`* must unambiguously reference a grouping column, unless the reference appears within an aggregate function or the ungrouped column is functionally dependent on the grouping columns.

The presence of `HAVING` turns a query into a grouped query even if there is no `GROUP BY` clause. This is the same as what happens when the query contains aggregate functions but no `GROUP BY` clause. All the selected rows are considered to form a single group, and the `SELECT` list and `HAVING` clause can only reference table columns from within aggregate functions. Such a query will emit a single row if the `HAVING` condition is true, zero rows if it is not true.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified with `HAVING`.

`WINDOW` Clause

The optional `WINDOW` clause has the general form

```
WINDOW window_name AS ( window_definition ) [, ...]
```

where *`window_name`* is a name that can be referenced from `OVER` clauses or subsequent window definitions, and *`window_definition`* is

```
[ existing_window_name ]
[ PARTITION BY expression [, ...] ]
[ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ...] ]
[ frame_clause ]
```

If an *`existing_window_name`* is specified it must refer to an earlier entry in the `WINDOW` list; the new window copies its partitioning clause from that entry, as well as its ordering clause if any. In this case the new window cannot specify its own `PARTITION BY` clause, and it can specify `ORDER BY` only if the copied window does not have one. The new window always uses its own frame clause; the copied window must not specify a frame clause.

The elements of the `PARTITION BY` list are interpreted in much the same fashion as elements of a *GROUP BY Clause*, except that they are always simple expressions and never the name or number of an output column. Another difference is that these expressions can contain aggregate function calls, which are not allowed in a regular `GROUP BY` clause. They are allowed here because windowing occurs after grouping and aggregation.

Similarly, the elements of the `ORDER BY` list are interpreted in much the same fashion as elements of an *ORDER BY Clause*, except that the expressions are always taken as simple expressions and never the name or number of an output column.

The optional *`frame_clause`* defines the *window frame* for window functions that depend on the frame (not all do). The window frame is a set of related rows for each row of the query (called the *current row*). The *`frame_clause`* can be one of

```
[ RANGE | ROWS ] frame_start
[ RANGE | ROWS ] BETWEEN frame_start AND frame_end
```

where *frame_start* and *frame_end* can be one of

```
UNBOUNDED PRECEDING
value PRECEDING
CURRENT ROW
value FOLLOWING
UNBOUNDED FOLLOWING
```

If *frame_end* is omitted it defaults to CURRENT ROW. Restrictions are that *frame_start* cannot be UNBOUNDED FOLLOWING, *frame_end* cannot be UNBOUNDED PRECEDING, and the *frame_end* choice cannot appear earlier in the above list than the *frame_start* choice — for example RANGE BETWEEN CURRENT ROW AND *value* PRECEDING is not allowed.

The default framing option is RANGE UNBOUNDED PRECEDING, which is the same as RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW; it sets the frame to be all rows from the partition start up through the current row's last peer (a row that ORDER BY considers equivalent to the current row, or all rows if there is no ORDER BY). In general, UNBOUNDED PRECEDING means that the frame starts with the first row of the partition, and similarly UNBOUNDED FOLLOWING means that the frame ends with the last row of the partition (regardless of RANGE or ROWS mode). In ROWS mode, CURRENT ROW means that the frame starts or ends with the current row; but in RANGE mode it means that the frame starts or ends with the current row's first or last peer in the ORDER BY ordering. The *value* PRECEDING and *value* FOLLOWING cases are currently only allowed in ROWS mode. They indicate that the frame starts or ends with the row that many rows before or after the current row. *value* must be an integer expression not containing any variables, aggregate functions, or window functions. The value must not be null or negative; but it can be zero, which selects the current row itself.

Beware that the ROWS options can produce unpredictable results if the ORDER BY ordering does not order the rows uniquely. The RANGE options are designed to ensure that rows that are peers in the ORDER BY ordering are treated alike; all peer rows will be in the same frame.

The purpose of a WINDOW clause is to specify the behavior of *window functions* appearing in the query's *SELECT List* or *ORDER BY Clause*. These functions can reference the WINDOW clause entries by name in their OVER clauses. A WINDOW clause entry does not have to be referenced anywhere, however; if it is not used in the query it is simply ignored. It is possible to use window functions without any WINDOW clause at all, since a window function call can specify its window definition directly in its OVER clause. However, the WINDOW clause saves typing when the same window definition is needed for more than one window function.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified with WINDOW.

Window functions are described in detail in Section 3.5, Section 4.2.8, and Section 7.2.4.

SELECT List

The SELECT list (between the key words SELECT and FROM) specifies expressions that form the output rows of the SELECT statement. The expressions can (and usually do) refer to columns computed in the FROM clause.

Just as in a table, every output column of a SELECT has a name. In a simple SELECT this name is just used to label the column for display, but when the SELECT is a sub-query of a larger query, the name is seen by the larger query as the column name of the virtual table produced by the sub-query. To

specify the name to use for an output column, write AS *output_name* after the column's expression. (You can omit AS, but only if the desired output name does not match any PostgreSQL keyword (see Appendix C). For protection against possible future keyword additions, it is recommended that you always either write AS or double-quote the output name.) If you do not specify a column name, a name is chosen automatically by PostgreSQL. If the column's expression is a simple column reference then the chosen name is the same as that column's name. In more complex cases a function or type name may be used, or the system may fall back on a generated name such as ?column?.

An output column's name can be used to refer to the column's value in ORDER BY and GROUP BY clauses, but not in the WHERE or HAVING clauses; there you must write out the expression instead.

Instead of an expression, * can be written in the output list as a shorthand for all the columns of the selected rows. Also, you can write *table_name*.* as a shorthand for the columns coming from just that table. In these cases it is not possible to specify new names with AS; the output column names will be the same as the table columns' names.

DISTINCT Clause

If SELECT DISTINCT is specified, all duplicate rows are removed from the result set (one row is kept from each group of duplicates). SELECT ALL specifies the opposite: all rows are kept; that is the default.

SELECT DISTINCT ON (*expression* [, ...]) keeps only the first row of each set of rows where the given expressions evaluate to equal. The DISTINCT ON expressions are interpreted using the same rules as for ORDER BY (see above). Note that the "first row" of each set is unpredictable unless ORDER BY is used to ensure that the desired row appears first. For example:

```
SELECT DISTINCT ON (location) location, time, report
    FROM weather_reports
    ORDER BY location, time DESC;
```

retrieves the most recent weather report for each location. But if we had not used ORDER BY to force descending order of time values for each location, we'd have gotten a report from an unpredictable time for each location.

The DISTINCT ON expression(s) must match the leftmost ORDER BY expression(s). The ORDER BY clause will normally contain additional expression(s) that determine the desired precedence of rows within each DISTINCT ON group.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified with DISTINCT.

UNION Clause

The UNION clause has this general form:

```
select_statement UNION [ ALL | DISTINCT ] select_statement
```

select_statement is any SELECT statement without an ORDER BY, LIMIT, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE, or FOR KEY SHARE clause. (ORDER BY and LIMIT can be attached to a subexpression if it is enclosed in parentheses. Without parentheses, these clauses will be taken to apply to the result of the UNION, not to its right-hand input expression.)

The UNION operator computes the set union of the rows returned by the involved SELECT statements. A row is in the set union of two result sets if it appears in at least one of the result sets. The two

`SELECT` statements that represent the direct operands of the `UNION` must produce the same number of columns, and corresponding columns must be of compatible data types.

The result of `UNION` does not contain any duplicate rows unless the `ALL` option is specified. `ALL` prevents elimination of duplicates. (Therefore, `UNION ALL` is usually significantly quicker than `UNION`; use `ALL` when you can.) `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `UNION` operators in the same `SELECT` statement are evaluated left to right, unless otherwise indicated by parentheses.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified either for a `UNION` result or for any input of a `UNION`.

`INTERSECT` Clause

The `INTERSECT` clause has this general form:

```
select_statement INTERSECT [ ALL | DISTINCT ] select_statement
```

`select_statement` is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause.

The `INTERSECT` operator computes the set intersection of the rows returned by the involved `SELECT` statements. A row is in the intersection of two result sets if it appears in both result sets.

The result of `INTERSECT` does not contain any duplicate rows unless the `ALL` option is specified. With `ALL`, a row that has *`m`* duplicates in the left table and *`n`* duplicates in the right table will appear min(*`m`*,*`n`*) times in the result set. `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `INTERSECT` operators in the same `SELECT` statement are evaluated left to right, unless parentheses dictate otherwise. `INTERSECT` binds more tightly than `UNION`. That is, `A UNION B INTERSECT C` will be read as `A UNION (B INTERSECT C)`.

Currently, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE` and `FOR KEY SHARE` cannot be specified either for an `INTERSECT` result or for any input of an `INTERSECT`.

`EXCEPT` Clause

The `EXCEPT` clause has this general form:

```
select_statement EXCEPT [ ALL | DISTINCT ] select_statement
```

`select_statement` is any `SELECT` statement without an `ORDER BY`, `LIMIT`, `FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, or `FOR KEY SHARE` clause.

The `EXCEPT` operator computes the set of rows that are in the result of the left `SELECT` statement but not in the result of the right one.

The result of `EXCEPT` does not contain any duplicate rows unless the `ALL` option is specified. With `ALL`, a row that has *`m`* duplicates in the left table and *`n`* duplicates in the right table will appear max(*`m`*-*`n`*,0) times in the result set. `DISTINCT` can be written to explicitly specify the default behavior of eliminating duplicate rows.

Multiple `EXCEPT` operators in the same `SELECT` statement are evaluated left to right, unless parentheses dictate otherwise. `EXCEPT` binds at the same level as `UNION`.

Currently, FOR NO KEY UPDATE, FOR UPDATE, FOR SHARE and FOR KEY SHARE cannot be specified either for an EXCEPT result or for any input of an EXCEPT.

ORDER BY Clause

The optional ORDER BY clause has this general form:

```
ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ...]
```

The ORDER BY clause causes the result rows to be sorted according to the specified expression(s). If two rows are equal according to the leftmost expression, they are compared according to the next expression and so on. If they are equal according to all specified expressions, they are returned in an implementation-dependent order.

Each *expression* can be the name or ordinal number of an output column (SELECT list item), or it can be an arbitrary expression formed from input-column values.

The ordinal number refers to the ordinal (left-to-right) position of the output column. This feature makes it possible to define an ordering on the basis of a column that does not have a unique name. This is never absolutely necessary because it is always possible to assign a name to an output column using the AS clause.

It is also possible to use arbitrary expressions in the ORDER BY clause, including columns that do not appear in the SELECT output list. Thus the following statement is valid:

```
SELECT name FROM distributors ORDER BY code;
```

A limitation of this feature is that an ORDER BY clause applying to the result of a UNION, INTERSECT, or EXCEPT clause can only specify an output column name or number, not an expression.

If an ORDER BY expression is a simple name that matches both an output column name and an input column name, ORDER BY will interpret it as the output column name. This is the opposite of the choice that GROUP BY will make in the same situation. This inconsistency is made to be compatible with the SQL standard.

Optionally one can add the key word ASC (ascending) or DESC (descending) after any expression in the ORDER BY clause. If not specified, ASC is assumed by default. Alternatively, a specific ordering operator name can be specified in the USING clause. An ordering operator must be a less-than or greater-than member of some B-tree operator family. ASC is usually equivalent to USING < and DESC is usually equivalent to USING >. (But the creator of a user-defined data type can define exactly what the default sort ordering is, and it might correspond to operators with other names.)

If NULLS LAST is specified, null values sort after all non-null values; if NULLS FIRST is specified, null values sort before all non-null values. If neither is specified, the default behavior is NULLS LAST when ASC is specified or implied, and NULLS FIRST when DESC is specified (thus, the default is to act as though nulls are larger than non-nulls). When USING is specified, the default nulls ordering depends on whether the operator is a less-than or greater-than operator.

Note that ordering options apply only to the expression they follow; for example ORDER BY x, y DESC does not mean the same thing as ORDER BY x DESC, y DESC.

Character-string data is sorted according to the collation that applies to the column being sorted. That can be overridden at need by including a COLLATE clause in the *expression*, for example ORDER BY mycolumn COLLATE "en_US". For more information see Section 4.2.10 and Section 22.2.

`LIMIT` Clause

The `LIMIT` clause consists of two independent sub-clauses:

```
LIMIT { count | ALL }
OFFSET start
```

`count` specifies the maximum number of rows to return, while *`start`* specifies the number of rows to skip before starting to return rows. When both are specified, *`start`* rows are skipped before starting to count the *`count`* rows to be returned.

If the *`count`* expression evaluates to NULL, it is treated as `LIMIT ALL`, i.e., no limit. If *`start`* evaluates to NULL, it is treated the same as `OFFSET 0`.

SQL:2008 introduced a different syntax to achieve the same result, which PostgreSQL also supports. It is:

```
OFFSET start { ROW | ROWS }
FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY
```

In this syntax, to write anything except a simple integer constant for *`start`* or *`count`*, you must write parentheses around it. If *`count`* is omitted in a `FETCH` clause, it defaults to 1. `ROW` and `ROWS` as well as `FIRST` and `NEXT` are noise words that don't influence the effects of these clauses. According to the standard, the `OFFSET` clause must come before the `FETCH` clause if both are present; but PostgreSQL is laxer and allows either order.

When using `LIMIT`, it is a good idea to use an `ORDER BY` clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query's rows — you might be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? You don't know what ordering unless you specify `ORDER BY`.

The query planner takes `LIMIT` into account when generating a query plan, so you are very likely to get different plans (yielding different row orders) depending on what you use for `LIMIT` and `OFFSET`. Thus, using different `LIMIT`/`OFFSET` values to select different subsets of a query result *will give inconsistent results* unless you enforce a predictable result ordering with `ORDER BY`. This is not a bug; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless `ORDER BY` is used to constrain the order.

It is even possible for repeated executions of the same `LIMIT` query to return different subsets of the rows of a table, if there is not an `ORDER BY` to enforce selection of a deterministic subset. Again, this is not a bug; determinism of the results is simply not guaranteed in such a case.

The Locking Clause

`FOR UPDATE`, `FOR NO KEY UPDATE`, `FOR SHARE` and `FOR KEY SHARE` are *locking clauses*; they affect how `SELECT` locks rows as they are obtained from the table.

The locking clause has the general form

```
FOR lock_strength [ OF table_name [, ...] ] [ NOWAIT ]
```

where *`lock_strength`* can be one of

```
UPDATE
NO KEY UPDATE
SHARE
KEY SHARE
```

For more information on each row-level lock mode, refer to Section 13.3.2.

To prevent the operation from waiting for other transactions to commit, use the `NOWAIT` option. With `NOWAIT`, the statement reports an error, rather than waiting, if a selected row cannot be locked immediately. Note that `NOWAIT` applies only to the row-level lock(s) — the required `ROW SHARE` table-level lock is still taken in the ordinary way (see Chapter 13). You can use LOCK with the `NOWAIT` option first, if you need to acquire the table-level lock without waiting.

If specific tables are named in a locking clause, then only rows coming from those tables are locked; any other tables used in the `SELECT` are simply read as usual. A locking clause without a table list affects all tables used in the statement. If a locking clause is applied to a view or sub-query, it affects all tables used in the view or sub-query. However, these clauses do not apply to `WITH` queries referenced by the primary query. If you want row locking to occur within a `WITH` query, specify a locking clause within the `WITH` query.

Multiple locking clauses can be written if it is necessary to specify different locking behavior for different tables. If the same table is mentioned (or implicitly affected) by more than one locking clause, then it is processed as if it was only specified by the strongest one. Similarly, a table is processed as `NOWAIT` if that is specified in any of the clauses affecting it.

The locking clauses cannot be used in contexts where returned rows cannot be clearly identified with individual table rows; for example they cannot be used with aggregation.

When a locking clause appears at the top level of a `SELECT` query, the rows that are locked are exactly those that are returned by the query; in the case of a join query, the rows locked are those that contribute to returned join rows. In addition, rows that satisfied the query conditions as of the query snapshot will be locked, although they will not be returned if they were updated after the snapshot and no longer satisfy the query conditions. If a `LIMIT` is used, locking stops once enough rows have been returned to satisfy the limit (but note that rows skipped over by `OFFSET` will get locked). Similarly, if a locking clause is used in a cursor's query, only rows actually fetched or stepped past by the cursor will be locked.

When a locking clause appears in a sub-`SELECT`, the rows locked are those returned to the outer query by the sub-query. This might involve fewer rows than inspection of the sub-query alone would suggest, since conditions from the outer query might be used to optimize execution of the sub-query. For example,

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss WHERE col1 = 5;
```

will lock only rows having `col1 = 5`, even though that condition is not textually within the sub-query.

Previous releases failed to preserve a lock which is upgraded by a later savepoint. For example, this code:

```
BEGIN;
SELECT * FROM mytable WHERE key = 1 FOR UPDATE;
SAVEPOINT s;
UPDATE mytable SET ... WHERE key = 1;
ROLLBACK TO s;
```

would fail to preserve the `FOR UPDATE` lock after the `ROLLBACK TO`. This has been fixed in release 9.3.

Caution

It is possible for a SELECT command running at the READ COMMITTED transaction isolation level and using ORDER BY and a locking clause to return rows out of order. This is because ORDER BY is applied first. The command sorts the result, but might then block trying to obtain a lock on one or more of the rows. Once the SELECT unblocks, some of the ordering column values might have been modified, leading to those rows appearing to be out of order (though they are in order in terms of the original column values). This can be worked around at need by placing the FOR UPDATE/SHARE clause in a sub-query, for example

```
SELECT * FROM (SELECT * FROM mytable FOR UPDATE) ss ORDER BY column1;
```

Note that this will result in locking all rows of mytable, whereas FOR UPDATE at the top level would lock only the actually returned rows. This can make for a significant performance difference, particularly if the ORDER BY is combined with LIMIT or other restrictions. So this technique is recommended only if concurrent updates of the ordering columns are expected and a strictly sorted result is required.

At the REPEATABLE READ or SERIALIZABLE transaction isolation level this would cause a serialization failure (with a SQLSTATE of '40001'), so there is no possibility of receiving rows out of order under these isolation levels.

TABLE Command

The command

```
TABLE name
```

is equivalent to

```
SELECT * FROM name
```

It can be used as a top-level command or as a space-saving syntax variant in parts of complex queries. Only the WITH, UNION, INTERSECT, EXCEPT, ORDER BY, LIMIT, OFFSET, FETCH and FOR locking clauses can be used with TABLE; the WHERE clause and any form of aggregation cannot be used.

Examples

To join the table films with the table distributors:

```
SELECT f.title, f.did, d.name, f.date_prod, f.kind
    FROM distributors d, films f
    WHERE f.did = d.did

       title       | did |     name     | date_prod  |   kind
-------------------+-----+--------------+------------+----------
 The Third Man     | 101 | British Lion | 1949-12-23 | Drama
 The African Queen | 101 | British Lion | 1951-08-11 | Romantic
 ...
```

To sum the column `len` of all films and group the results by `kind`:

```
SELECT kind, sum(len) AS total FROM films GROUP BY kind;
```

```
   kind   | total
----------+-------
 Action   | 07:34
 Comedy   | 02:58
 Drama    | 14:28
 Musical  | 06:42
 Romantic | 04:38
```

To sum the column `len` of all films, group the results by `kind` and show those group totals that are less than 5 hours:

```
SELECT kind, sum(len) AS total
    FROM films
    GROUP BY kind
    HAVING sum(len) < interval '5 hours';
```

```
   kind   | total
----------+-------
 Comedy   | 02:58
 Romantic | 04:38
```

The following two examples are identical ways of sorting the individual results according to the contents of the second column (`name`):

```
SELECT * FROM distributors ORDER BY name;
SELECT * FROM distributors ORDER BY 2;
```

```
 did |       name
-----+------------------
 109 | 20th Century Fox
 110 | Bavaria Atelier
 101 | British Lion
 107 | Columbia
 102 | Jean Luc Godard
 113 | Luso films
 104 | Mosfilm
 103 | Paramount
 106 | Toho
 105 | United Artists
 111 | Walt Disney
 112 | Warner Bros.
 108 | Westward
```

The next example shows how to obtain the union of the tables `distributors` and `actors`, restricting the results to those that begin with the letter W in each table. Only distinct rows are wanted, so the key word `ALL` is omitted.

```
distributors:               actors:
 did |     name              id |     name
```

```
-----+--------------        ----+----------------
 108 | Westward                1 | Woody Allen
 111 | Walt Disney             2 | Warren Beatty
 112 | Warner Bros.            3 | Walter Matthau
 ...                          ...
```

```
SELECT distributors.name
    FROM distributors
    WHERE distributors.name LIKE 'W%'
UNION
SELECT actors.name
    FROM actors
    WHERE actors.name LIKE 'W%';

      name
----------------
 Walt Disney
 Walter Matthau
 Warner Bros.
 Warren Beatty
 Westward
 Woody Allen
```

This example shows how to use a function in the `FROM` clause, both with and without a column definition list:

```
CREATE FUNCTION distributors(int) RETURNS SETOF distributors AS $$
    SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;

SELECT * FROM distributors(111);
 did |    name
-----+-------------
 111 | Walt Disney

CREATE FUNCTION distributors_2(int) RETURNS SETOF record AS $$
    SELECT * FROM distributors WHERE did = $1;
$$ LANGUAGE SQL;

SELECT * FROM distributors_2(111) AS (f1 int, f2 text);
 f1  |     f2
-----+-------------
 111 | Walt Disney
```

Here is an example of a function with an ordinality column added:

```
SELECT * FROM unnest(ARRAY['a','b','c','d','e','f']) WITH ORDINALITY;
 unnest | ordinality
--------+----------
 a      |        1
 b      |        2
 c      |        3
 d      |        4
 e      |        5
```

```
 f      |         6
(6 rows)
```

This example shows how to use a simple `WITH` clause:

```
WITH t AS (
    SELECT random() as x FROM generate_series(1, 3)
  )
SELECT * FROM t
UNION ALL
SELECT * FROM t

         x
--------------------
  0.534150459803641
  0.520092216785997
 0.0735620250925422
  0.534150459803641
  0.520092216785997
 0.0735620250925422
```

Notice that the `WITH` query was evaluated only once, so that we got two sets of the same three random values.

This example uses `WITH RECURSIVE` to find all subordinates (direct or indirect) of the employee Mary, and their level of indirectness, from a table that shows only direct subordinates:

```
WITH RECURSIVE employee_recursive(distance, employee_name, manager_name) AS (
    SELECT 1, employee_name, manager_name
    FROM employee
    WHERE manager_name = 'Mary'
  UNION ALL
    SELECT er.distance + 1, e.employee_name, e.manager_name
    FROM employee_recursive er, employee e
    WHERE er.employee_name = e.manager_name
  )
SELECT distance, employee_name FROM employee_recursive;
```

Notice the typical form of recursive queries: an initial condition, followed by `UNION`, followed by the recursive part of the query. Be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. (See Section 7.8 for more examples.)

This example uses `LATERAL` to apply a set-returning function `get_product_names()` for each row of the `manufacturers` table:

```
SELECT m.name AS mname, pname
FROM manufacturers m, LATERAL get_product_names(m.id) pname;
```

Manufacturers not currently having any products would not appear in the result, since it is an inner join. If we wished to include the names of such manufacturers in the result, we could do:

```
SELECT m.name AS mname, pname
FROM manufacturers m LEFT JOIN LATERAL get_product_names(m.id) pname ON true;
```

Compatibility

Of course, the SELECT statement is compatible with the SQL standard. But there are some extensions and some missing features.

Omitted FROM Clauses

PostgreSQL allows one to omit the FROM clause. It has a straightforward use to compute the results of simple expressions:

```
SELECT 2+2;

 ?column?
----------
        4
```

Some other SQL databases cannot do this except by introducing a dummy one-row table from which to do the SELECT.

Note that if a FROM clause is not specified, the query cannot reference any database tables. For example, the following query is invalid:

```
SELECT distributors.* WHERE distributors.name = 'Westward';
```

PostgreSQL releases prior to 8.1 would accept queries of this form, and add an implicit entry to the query's FROM clause for each table referenced by the query. This is no longer allowed.

Empty SELECT Lists

The list of output expressions after SELECT can be empty, producing a zero-column result table. This is not valid syntax according to the SQL standard. PostgreSQL allows it to be consistent with allowing zero-column tables. However, an empty list is not allowed when DISTINCT is used.

Omitting the AS Key Word

In the SQL standard, the optional key word AS can be omitted before an output column name whenever the new column name is a valid column name (that is, not the same as any reserved keyword). PostgreSQL is slightly more restrictive: AS is required if the new column name matches any keyword at all, reserved or not. Recommended practice is to use AS or double-quote output column names, to prevent any possible conflict against future keyword additions.

In FROM items, both the standard and PostgreSQL allow AS to be omitted before an alias that is an unreserved keyword. But this is impractical for output column names, because of syntactic ambiguities.

ONLY and Inheritance

The SQL standard requires parentheses around the table name when writing ONLY, for example SELECT * FROM ONLY (tab1), ONLY (tab2) WHERE .... PostgreSQL considers these parentheses to be optional.

PostgreSQL allows a trailing * to be written to explicitly specify the non-ONLY behavior of including child tables. The standard does not allow this.

(These points apply equally to all SQL commands supporting the ONLY option.)

Function Calls in `FROM`

PostgreSQL allows a function call to be written directly as a member of the `FROM` list. In the SQL standard it would be necessary to wrap such a function call in a sub-`SELECT`; that is, the syntax `FROM` *`func`*`(...)` *`alias`* is approximately equivalent to `FROM LATERAL (SELECT` *`func`*`(...))` *`alias`*. Note that `LATERAL` is considered to be implicit; this is because the standard requires `LATERAL` semantics for an `UNNEST()` item in `FROM`. PostgreSQL treats `UNNEST()` the same as other set-returning functions.

Namespace Available to `GROUP BY` and `ORDER BY`

In the SQL-92 standard, an `ORDER BY` clause can only use output column names or numbers, while a `GROUP BY` clause can only use expressions based on input column names. PostgreSQL extends each of these clauses to allow the other choice as well (but it uses the standard's interpretation if there is ambiguity). PostgreSQL also allows both clauses to specify arbitrary expressions. Note that names appearing in an expression will always be taken as input-column names, not as output-column names.

SQL:1999 and later use a slightly different definition which is not entirely upward compatible with SQL-92. In most cases, however, PostgreSQL will interpret an `ORDER BY` or `GROUP BY` expression the same way SQL:1999 does.

Functional Dependencies

PostgreSQL recognizes functional dependency (allowing columns to be omitted from `GROUP BY`) only when a table's primary key is included in the `GROUP BY` list. The SQL standard specifies additional conditions that should be recognized.

`WINDOW` Clause Restrictions

The SQL standard provides additional options for the window *`frame_clause`*. PostgreSQL currently supports only the options listed above.

`LIMIT` and `OFFSET`

The clauses `LIMIT` and `OFFSET` are PostgreSQL-specific syntax, also used by MySQL. The SQL:2008 standard has introduced the clauses `OFFSET ... FETCH {FIRST|NEXT} ...` for the same functionality, as shown above in *LIMIT Clause*. This syntax is also used by IBM DB2. (Applications written for Oracle frequently use a workaround involving the automatically generated `rownum` column, which is not available in PostgreSQL, to implement the effects of these clauses.)

`FOR NO KEY UPDATE`, `FOR UPDATE`, `FOR SHARE`, `FOR KEY SHARE`

Although `FOR UPDATE` appears in the SQL standard, the standard allows it only as an option of `DECLARE CURSOR`. PostgreSQL allows it in any `SELECT` query as well as in sub-`SELECT`s, but this is an extension. The `FOR NO KEY UPDATE`, `FOR SHARE` and `FOR KEY SHARE` variants, as well as the `NOWAIT` option, do not appear in the standard.

Data-Modifying Statements in `WITH`

PostgreSQL allows `INSERT`, `UPDATE`, and `DELETE` to be used as `WITH` queries. This is not found in the SQL standard.

Nonstandard Clauses

`DISTINCT ON ( ... )` is an extension of the SQL standard.

`ROWS FROM( ... )` is an extension of the SQL standard.

SELECT INTO

Name

SELECT INTO — define a new table from the results of a query

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON ( expression [, ...] ) ] ]
    * | expression [ [ AS ] output_name ] [, ...]
    INTO [ TEMPORARY | TEMP | UNLOGGED ] [ TABLE ] new_table
    [ FROM from_item [, ...] ]
    [ WHERE condition ]
    [ GROUP BY expression [, ...] ]
    [ HAVING condition [, ...] ]
    [ WINDOW window_name AS ( window_definition ) [, ...] ]
    [ { UNION | INTERSECT | EXCEPT } [ ALL | DISTINCT ] select ]
    [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ] [, ..
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
    [ FOR { UPDATE | SHARE } [ OF table_name [, ...] ] [ NOWAIT ] [...] ]
```

Description

SELECT INTO creates a new table and fills it with data computed by a query. The data is not returned to the client, as it is with a normal SELECT. The new table's columns have the names and data types associated with the output columns of the SELECT.

Parameters

TEMPORARY or TEMP

If specified, the table is created as a temporary table. Refer to CREATE TABLE for details.

UNLOGGED

If specified, the table is created as an unlogged table. Refer to CREATE TABLE for details.

new_table

The name (optionally schema-qualified) of the table to be created.

All other parameters are described in detail under SELECT.

Notes

CREATE TABLE AS is functionally similar to SELECT INTO. CREATE TABLE AS is the recommended syntax, since this form of SELECT INTO is not available in ECPG or PL/pgSQL, because

they interpret the `INTO` clause differently. Furthermore, `CREATE TABLE AS` offers a superset of the functionality provided by `SELECT INTO`.

To add OIDs to the table created by `SELECT INTO`, enable the default_with_oids configuration variable. Alternatively, `CREATE TABLE AS` can be used with the `WITH OIDS` clause.

Examples

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
SELECT * INTO films_recent FROM films WHERE date_prod >= '2002-01-01';
```

Compatibility

The SQL standard uses `SELECT INTO` to represent selecting values into scalar variables of a host program, rather than creating a new table. This indeed is the usage found in ECPG (see Chapter 33) and PL/pgSQL (see Chapter 40). The PostgreSQL usage of `SELECT INTO` to represent table creation is historical. It is best to use `CREATE TABLE AS` for this purpose in new code.

See Also

CREATE TABLE AS

SET

Name

SET — change a run-time parameter

Synopsis

```
SET [ SESSION | LOCAL ] configuration_parameter { TO | = } { value | 'value' | DEFAULT }
SET [ SESSION | LOCAL ] TIME ZONE { timezone | LOCAL | DEFAULT }
```

Description

The SET command changes run-time configuration parameters. Many of the run-time parameters listed in Chapter 18 can be changed on-the-fly with SET. (But some require superuser privileges to change, and others cannot be changed after server or session start.) SET only affects the value used by the current session.

If SET (or equivalently SET SESSION) is issued within a transaction that is later aborted, the effects of the SET command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another SET.

The effects of SET LOCAL last only till the end of the current transaction, whether committed or not. A special case is SET followed by SET LOCAL within a single transaction: the SET LOCAL value will be seen until the end of the transaction, but afterwards (if the transaction is committed) the SET value will take effect.

The effects of SET or SET LOCAL are also canceled by rolling back to a savepoint that is earlier than the command.

If SET LOCAL is used within a function that has a SET option for the same variable (see CREATE FUNCTION), the effects of the SET LOCAL command disappear at function exit; that is, the value in effect when the function was called is restored anyway. This allows SET LOCAL to be used for dynamic or repeated changes of a parameter within a function, while still having the convenience of using the SET option to save and restore the caller's value. However, a regular SET command overrides any surrounding function's SET option; its effects will persist unless rolled back.

> **Note:** In PostgreSQL versions 8.0 through 8.2, the effects of a SET LOCAL would be canceled by releasing an earlier savepoint, or by successful exit from a PL/pgSQL exception block. This behavior has been changed because it was deemed unintuitive.

Parameters

SESSION

Specifies that the command takes effect for the current session. (This is the default if neither SESSION nor LOCAL appears.)

`LOCAL`

Specifies that the command takes effect for only the current transaction. After `COMMIT` or `ROLLBACK`, the session-level setting takes effect again. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

`configuration_parameter`

Name of a settable run-time parameter. Available parameters are documented in Chapter 18 and below.

`value`

New value of parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these, as appropriate for the particular parameter. `DEFAULT` can be written to specify resetting the parameter to its default value (that is, whatever value it would have had if no `SET` had been executed in the current session).

Besides the configuration parameters documented in Chapter 18, there are a few that can only be adjusted using the `SET` command or that have a special syntax:

`SCHEMA`

`SET SCHEMA '`*`value`*`'` is an alias for `SET search_path TO` *`value`*. Only one schema can be specified using this syntax.

`NAMES`

`SET NAMES` *`value`* is an alias for `SET client_encoding TO` *`value`*.

`SEED`

Sets the internal seed for the random number generator (the function `random`). Allowed values are floating-point numbers between -1 and 1, which are then multiplied by 2^{31}-1.

The seed can also be set by invoking the function `setseed`:

```
SELECT setseed(value);
```

`TIME ZONE`

`SET TIME ZONE` *`value`* is an alias for `SET timezone TO` *`value`*. The syntax `SET TIME ZONE` allows special syntax for the time zone specification. Here are examples of valid values:

`'PST8PDT'`

The time zone for Berkeley, California.

`'Europe/Rome'`

The time zone for Italy.

`-7`

The time zone 7 hours west from UTC (equivalent to PDT). Positive values are east from UTC.

`INTERVAL '-08:00' HOUR TO MINUTE`

The time zone 8 hours west from UTC (equivalent to PST).

`LOCAL`
`DEFAULT`

Set the time zone to your local time zone (that is, the server's default value of `timezone`).

Timezone settings given as numbers or intervals are internally translated to POSIX timezone syntax. For example, after `SET TIME ZONE -7`, `SHOW TIME ZONE` would report `<-07>+07`.

See Section 8.5.3 for more information about time zones.

Notes

The function `set_config` provides equivalent functionality; see Section 9.26. Also, it is possible to UPDATE the `pg_settings` system view to perform the equivalent of `SET`.

Examples

Set the schema search path:

```
SET search_path TO my_schema, public;
```

Set the style of date to traditional POSTGRES with "day before month" input convention:

```
SET datestyle TO postgres, dmy;
```

Set the time zone for Berkeley, California:

```
SET TIME ZONE 'PST8PDT';
```

Set the time zone for Italy:

```
SET TIME ZONE 'Europe/Rome';
```

Compatibility

`SET TIME ZONE` extends syntax defined in the SQL standard. The standard allows only numeric time zone offsets while PostgreSQL allows more flexible time-zone specifications. All other `SET` features are PostgreSQL extensions.

See Also

RESET, SHOW

SET CONSTRAINTS

Name

SET CONSTRAINTS — set constraint check timing for the current transaction

Synopsis

```
SET CONSTRAINTS { ALL | name [, ...] } { DEFERRED | IMMEDIATE }
```

Description

SET CONSTRAINTS sets the behavior of constraint checking within the current transaction. IMMEDIATE constraints are checked at the end of each statement. DEFERRED constraints are not checked until transaction commit. Each constraint has its own IMMEDIATE or DEFERRED mode.

Upon creation, a constraint is given one of three characteristics: DEFERRABLE INITIALLY DEFERRED, DEFERRABLE INITIALLY IMMEDIATE, or NOT DEFERRABLE. The third class is always IMMEDIATE and is not affected by the SET CONSTRAINTS command. The first two classes start every transaction in the indicated mode, but their behavior can be changed within a transaction by SET CONSTRAINTS.

SET CONSTRAINTS with a list of constraint names changes the mode of just those constraints (which must all be deferrable). Each constraint name can be schema-qualified. The current schema search path is used to find the first matching name if no schema name is specified. SET CONSTRAINTS ALL changes the mode of all deferrable constraints.

When SET CONSTRAINTS changes the mode of a constraint from DEFERRED to IMMEDIATE, the new mode takes effect retroactively: any outstanding data modifications that would have been checked at the end of the transaction are instead checked during the execution of the SET CONSTRAINTS command. If any such constraint is violated, the SET CONSTRAINTS fails (and does not change the constraint mode). Thus, SET CONSTRAINTS can be used to force checking of constraints to occur at a specific point in a transaction.

Currently, only UNIQUE, PRIMARY KEY, REFERENCES (foreign key), and EXCLUDE constraints are affected by this setting. NOT NULL and CHECK constraints are always checked immediately when a row is inserted or modified (*not* at the end of the statement). Uniqueness and exclusion constraints that have not been declared DEFERRABLE are also checked immediately.

The firing of triggers that are declared as "constraint triggers" is also controlled by this setting — they fire at the same time that the associated constraint should be checked.

Notes

Because PostgreSQL does not require constraint names to be unique within a schema (but only per-table), it is possible that there is more than one match for a specified constraint name. In this case SET CONSTRAINTS will act on all matches. For a non-schema-qualified name, once a match or matches have been found in some schema in the search path, schemas appearing later in the path are not searched.

This command only alters the behavior of constraints within the current transaction. Issuing this outside of a transaction block emits a warning and otherwise has no effect.

Compatibility

This command complies with the behavior defined in the SQL standard, except for the limitation that, in PostgreSQL, it does not apply to `NOT NULL` and `CHECK` constraints. Also, PostgreSQL checks non-deferrable uniqueness constraints immediately, not at end of statement as the standard would suggest.

SET ROLE

Name

SET ROLE — set the current user identifier of the current session

Synopsis

```
SET [ SESSION | LOCAL ] ROLE role_name
SET [ SESSION | LOCAL ] ROLE NONE
RESET ROLE
```

Description

This command sets the current user identifier of the current SQL session to be *role_name*. The role name can be written as either an identifier or a string literal. After SET ROLE, permissions checking for SQL commands is carried out as though the named role were the one that had logged in originally.

The specified *role_name* must be a role that the current session user is a member of. (If the session user is a superuser, any role can be selected.)

The SESSION and LOCAL modifiers act the same as for the regular SET command.

The NONE and RESET forms reset the current user identifier to be the current session user identifier. These forms can be executed by any user.

Notes

Using this command, it is possible to either add privileges or restrict one's privileges. If the session user role has the INHERITS attribute, then it automatically has all the privileges of every role that it could SET ROLE to; in this case SET ROLE effectively drops all the privileges assigned directly to the session user and to the other roles it is a member of, leaving only the privileges available to the named role. On the other hand, if the session user role has the NOINHERITS attribute, SET ROLE drops the privileges assigned directly to the session user and instead acquires the privileges available to the named role.

In particular, when a superuser chooses to SET ROLE to a non-superuser role, she loses her superuser privileges.

SET ROLE has effects comparable to SET SESSION AUTHORIZATION, but the privilege checks involved are quite different. Also, SET SESSION AUTHORIZATION determines which roles are allowable for later SET ROLE commands, whereas changing roles with SET ROLE does not change the set of roles allowed to a later SET ROLE.

SET ROLE does not process session variables as specified by the role's ALTER ROLE settings; this only happens during login.

SET ROLE cannot be used within a SECURITY DEFINER function.

Examples

```
SELECT SESSION_USER, CURRENT_USER;

 session_user | current_user
--------------+--------------
 peter        | peter

SET ROLE 'paul';

SELECT SESSION_USER, CURRENT_USER;

 session_user | current_user
--------------+--------------
 peter        | paul
```

Compatibility

PostgreSQL allows identifier syntax (`"rolename"`), while the SQL standard requires the role name to be written as a string literal. SQL does not allow this command during a transaction; PostgreSQL does not make this restriction because there is no reason to. The `SESSION` and `LOCAL` modifiers are a PostgreSQL extension, as is the `RESET` syntax.

See Also

SET SESSION AUTHORIZATION

SET SESSION AUTHORIZATION

Name

SET SESSION AUTHORIZATION — set the session user identifier and the current user identifier of the current session

Synopsis

```
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION user_name
SET [ SESSION | LOCAL ] SESSION AUTHORIZATION DEFAULT
RESET SESSION AUTHORIZATION
```

Description

This command sets the session user identifier and the current user identifier of the current SQL session to be *user_name*. The user name can be written as either an identifier or a string literal. Using this command, it is possible, for example, to temporarily become an unprivileged user and later switch back to being a superuser.

The session user identifier is initially set to be the (possibly authenticated) user name provided by the client. The current user identifier is normally equal to the session user identifier, but might change temporarily in the context of SECURITY DEFINER functions and similar mechanisms; it can also be changed by SET ROLE. The current user identifier is relevant for permission checking.

The session user identifier can be changed only if the initial session user (the *authenticated user*) had the superuser privilege. Otherwise, the command is accepted only if it specifies the authenticated user name.

The SESSION and LOCAL modifiers act the same as for the regular SET command.

The DEFAULT and RESET forms reset the session and current user identifiers to be the originally authenticated user name. These forms can be executed by any user.

Notes

SET SESSION AUTHORIZATION cannot be used within a SECURITY DEFINER function.

Examples

```
SELECT SESSION_USER, CURRENT_USER;

 session_user | current_user
--------------+--------------
 peter        | peter

SET SESSION AUTHORIZATION 'paul';

SELECT SESSION_USER, CURRENT_USER;
```

```
 session_user | current_user
--------------+--------------
 paul         | paul
```

Compatibility

The SQL standard allows some other expressions to appear in place of the literal *user_name*, but these options are not important in practice. PostgreSQL allows identifier syntax ("username"), which SQL does not. SQL does not allow this command during a transaction; PostgreSQL does not make this restriction because there is no reason to. The SESSION and LOCAL modifiers are a PostgreSQL extension, as is the RESET syntax.

The privileges necessary to execute this command are left implementation-defined by the standard.

See Also

SET ROLE

SET TRANSACTION

Name

SET TRANSACTION — set the characteristics of the current transaction

Synopsis

```
SET TRANSACTION transaction_mode [, ...]
SET TRANSACTION SNAPSHOT snapshot_id
SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode [, ...]

where transaction_mode is one of:

    ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED
    READ WRITE | READ ONLY
    [ NOT ] DEFERRABLE
```

Description

The SET TRANSACTION command sets the characteristics of the current transaction. It has no effect on any subsequent transactions. SET SESSION CHARACTERISTICS sets the default transaction characteristics for subsequent transactions of a session. These defaults can be overridden by SET TRANSACTION for an individual transaction.

The available transaction characteristics are the transaction isolation level, the transaction access mode (read/write or read-only), and the deferrable mode. In addition, a snapshot can be selected, though only for the current transaction, not as a session default.

The isolation level of a transaction determines what data the transaction can see when other transactions are running concurrently:

READ COMMITTED

A statement can only see rows committed before it began. This is the default.

REPEATABLE READ

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction.

SERIALIZABLE

All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction. If a pattern of reads and writes among concurrent serializable transactions would create a situation which could not have occurred for any serial (one-at-a-time) execution of those transactions, one of them will be rolled back with a serialization_failure error.

The SQL standard defines one additional level, READ UNCOMMITTED. In PostgreSQL READ UNCOMMITTED is treated as READ COMMITTED.

The transaction isolation level cannot be changed after the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of a transaction has been executed. See Chapter 13 for more information about transaction isolation and concurrency control.

The transaction access mode determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT, UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table; all CREATE, ALTER, and DROP commands; COMMENT, GRANT, REVOKE, TRUNCATE; and EXPLAIN ANALYZE and EXECUTE if the command they would execute is among those listed. This is a high-level notion of read-only that does not prevent all writes to disk.

The DEFERRABLE transaction property has no effect unless the transaction is also SERIALIZABLE and READ ONLY. When all three of these properties are selected for a transaction, the transaction may block when first acquiring its snapshot, after which it is able to run without the normal overhead of a SERIALIZABLE transaction and without any risk of contributing to or being canceled by a serialization failure. This mode is well suited for long-running reports or backups.

The SET TRANSACTION SNAPSHOT command allows a new transaction to run with the same *snapshot* as an existing transaction. The pre-existing transaction must have exported its snapshot with the pg_export_snapshot function (see Section 9.26.5). That function returns a snapshot identifier, which must be given to SET TRANSACTION SNAPSHOT to specify which snapshot is to be imported. The identifier must be written as a string literal in this command, for example '000003A1-1'. SET TRANSACTION SNAPSHOT can only be executed at the start of a transaction, before the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of the transaction. Furthermore, the transaction must already be set to SERIALIZABLE or REPEATABLE READ isolation level (otherwise, the snapshot would be discarded immediately, since READ COMMITTED mode takes a new snapshot for each command). If the importing transaction uses SERIALIZABLE isolation level, then the transaction that exported the snapshot must also use that isolation level. Also, a non-read-only serializable transaction cannot import a snapshot from a read-only transaction.

Notes

If SET TRANSACTION is executed without a prior START TRANSACTION or BEGIN, it emits a warning and otherwise has no effect.

It is possible to dispense with SET TRANSACTION by instead specifying the desired *transaction_modes* in BEGIN or START TRANSACTION. But that option is not available for SET TRANSACTION SNAPSHOT.

The session default transaction modes can also be set by setting the configuration parameters default_transaction_isolation, default_transaction_read_only, and default_transaction_deferrable. (In fact SET SESSION CHARACTERISTICS is just a verbose equivalent for setting these variables with SET.) This means the defaults can be set in the configuration file, via ALTER DATABASE, etc. Consult Chapter 18 for more information.

Examples

To begin a new transaction with the same snapshot as an already existing transaction, first export the snapshot from the existing transaction. That will return the snapshot identifier, for example:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SELECT pg_export_snapshot();
 pg_export_snapshot
--------------------
 000003A1-1
(1 row)
```

Then give the snapshot identifier in a `SET TRANSACTION SNAPSHOT` command at the beginning of the newly opened transaction:

```
BEGIN TRANSACTION ISOLATION LEVEL REPEATABLE READ;
SET TRANSACTION SNAPSHOT '000003A1-1';
```

Compatibility

These commands are defined in the SQL standard, except for the `DEFERRABLE` transaction mode and the `SET TRANSACTION SNAPSHOT` form, which are PostgreSQL extensions.

`SERIALIZABLE` is the default transaction isolation level in the standard. In PostgreSQL the default is ordinarily `READ COMMITTED`, but you can change it as mentioned above.

In the SQL standard, there is one other transaction characteristic that can be set with these commands: the size of the diagnostics area. This concept is specific to embedded SQL, and therefore is not implemented in the PostgreSQL server.

The SQL standard requires commas between successive *`transaction_modes`*, but for historical reasons PostgreSQL allows the commas to be omitted.

SHOW

Name

SHOW — show the value of a run-time parameter

Synopsis

```
SHOW name
SHOW ALL
```

Description

SHOW will display the current setting of run-time parameters. These variables can be set using the SET statement, by editing the postgresql.conf configuration file, through the PGOPTIONS environmental variable (when using libpq or a libpq-based application), or through command-line flags when starting the postgres server. See Chapter 18 for details.

Parameters

name

The name of a run-time parameter. Available parameters are documented in Chapter 18 and on the SET reference page. In addition, there are a few parameters that can be shown but not set:

SERVER_VERSION

Shows the server's version number.

SERVER_ENCODING

Shows the server-side character set encoding. At present, this parameter can be shown but not set, because the encoding is determined at database creation time.

LC_COLLATE

Shows the database's locale setting for collation (text ordering). At present, this parameter can be shown but not set, because the setting is determined at database creation time.

LC_CTYPE

Shows the database's locale setting for character classification. At present, this parameter can be shown but not set, because the setting is determined at database creation time.

IS_SUPERUSER

True if the current role has superuser privileges.

ALL

Show the values of all configuration parameters, with descriptions.

Notes

The function `current_setting` produces equivalent output; see Section 9.26. Also, the `pg_settings` system view produces the same information.

Examples

Show the current setting of the parameter `DateStyle`:

```
SHOW DateStyle;
 DateStyle
-----------
 ISO, MDY
(1 row)
```

Show the current setting of the parameter `geqo`:

```
SHOW geqo;
 geqo
------
 on
(1 row)
```

Show all settings:

```
SHOW ALL;
             name          | setting |                 description
---------------------------+---------+---------------------------------------------
 allow_system_table_mods | off     | Allows modifications of the structure of ...
    .
    .
    .
 xmloption               | content | Sets whether XML data in implicit parsing ...
 zero_damaged_pages      | off     | Continues processing past damaged page headers.
(196 rows)
```

Compatibility

The `SHOW` command is a PostgreSQL extension.

See Also

SET, RESET

START TRANSACTION

Name

START TRANSACTION — start a transaction block

Synopsis

```
START TRANSACTION [ transaction_mode [, ...] ]

where transaction_mode is one of:

    ISOLATION LEVEL { SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED
    READ WRITE | READ ONLY
    [ NOT ] DEFERRABLE
```

Description

This command begins a new transaction block. If the isolation level, read/write mode, or deferrable mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed. This is the same as the BEGIN command.

Parameters

Refer to SET TRANSACTION for information on the meaning of the parameters to this statement.

Compatibility

In the standard, it is not necessary to issue START TRANSACTION to start a transaction block: any SQL command implicitly begins a block. PostgreSQL's behavior can be seen as implicitly issuing a COMMIT after each command that does not follow START TRANSACTION (or BEGIN), and it is therefore often called "autocommit". Other relational database systems might offer an autocommit feature as a convenience.

The DEFERRABLE *transaction_mode* is a PostgreSQL language extension.

The SQL standard requires commas between successive *transaction_modes*, but for historical reasons PostgreSQL allows the commas to be omitted.

See also the compatibility section of SET TRANSACTION.

See Also

BEGIN, COMMIT, ROLLBACK, SAVEPOINT, SET TRANSACTION

TRUNCATE

Name

TRUNCATE — empty a table or set of tables

Synopsis

```
TRUNCATE [ TABLE ] [ ONLY ] name [ * ] [, ... ]
    [ RESTART IDENTITY | CONTINUE IDENTITY ] [ CASCADE | RESTRICT ]
```

Description

TRUNCATE quickly removes all rows from a set of tables. It has the same effect as an unqualified DELETE on each table, but since it does not actually scan the tables it is faster. Furthermore, it reclaims disk space immediately, rather than requiring a subsequent VACUUM operation. This is most useful on large tables.

Parameters

name

The name (optionally schema-qualified) of a table to truncate. If ONLY is specified before the table name, only that table is truncated. If ONLY is not specified, the table and all its descendant tables (if any) are truncated. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

RESTART IDENTITY

Automatically restart sequences owned by columns of the truncated table(s).

CONTINUE IDENTITY

Do not change the values of sequences. This is the default.

CASCADE

Automatically truncate all tables that have foreign-key references to any of the named tables, or to any tables added to the group due to CASCADE.

RESTRICT

Refuse to truncate if any of the tables have foreign-key references from tables that are not listed in the command. This is the default.

Notes

You must have the TRUNCATE privilege on a table to truncate it.

TRUNCATE acquires an ACCESS EXCLUSIVE lock on each table it operates on, which blocks all other concurrent operations on the table. When RESTART IDENTITY is specified, any sequences that are to be restarted are likewise locked exclusively. If concurrent access to a table is required, then the DELETE command should be used instead.

`TRUNCATE` cannot be used on a table that has foreign-key references from other tables, unless all such tables are also truncated in the same command. Checking validity in such cases would require table scans, and the whole point is not to do one. The `CASCADE` option can be used to automatically include all dependent tables — but be very careful when using this option, or else you might lose data you did not intend to!

`TRUNCATE` will not fire any `ON DELETE` triggers that might exist for the tables. But it will fire `ON TRUNCATE` triggers. If `ON TRUNCATE` triggers are defined for any of the tables, then all `BEFORE TRUNCATE` triggers are fired before any truncation happens, and all `AFTER TRUNCATE` triggers are fired after the last truncation is performed and any sequences are reset. The triggers will fire in the order that the tables are to be processed (first those listed in the command, and then any that were added due to cascading).

> **Warning**
>
> `TRUNCATE` is not MVCC-safe (see Chapter 13 for general information about MVCC). After truncation, the table will appear empty to all concurrent transactions, even if they are using a snapshot taken before the truncation occurred. This will only be an issue for a transaction that did not access the truncated table before the truncation happened — any transaction that has done so would hold at least an `ACCESS SHARE` lock, which would block `TRUNCATE` until that transaction completes. So truncation will not cause any apparent inconsistency in the table contents for successive queries on the same table, but it could cause visible inconsistency between the contents of the truncated table and other tables in the database.

`TRUNCATE` is transaction-safe with respect to the data in the tables: the truncation will be safely rolled back if the surrounding transaction does not commit.

When `RESTART IDENTITY` is specified, the implied `ALTER SEQUENCE RESTART` operations are also done transactionally; that is, they will be rolled back if the surrounding transaction does not commit. This is unlike the normal behavior of `ALTER SEQUENCE RESTART`. Be aware that if any additional sequence operations are done on the restarted sequences before the transaction rolls back, the effects of these operations on the sequences will be rolled back, but not their effects on `currval()`; that is, after the transaction `currval()` will continue to reflect the last sequence value obtained inside the failed transaction, even though the sequence itself may no longer be consistent with that. This is similar to the usual behavior of `currval()` after a failed transaction.

Examples

Truncate the tables `bigtable` and `fattable`:

```
TRUNCATE bigtable, fattable;
```

The same, and also reset any associated sequence generators:

```
TRUNCATE bigtable, fattable RESTART IDENTITY;
```

Truncate the table `othertable`, and cascade to any tables that reference `othertable` via foreign-key constraints:

```
TRUNCATE othertable CASCADE;
```

Compatibility

The SQL:2008 standard includes a `TRUNCATE` command with the syntax `TRUNCATE TABLE` *`tablename`*. The clauses `CONTINUE IDENTITY`/`RESTART IDENTITY` also appear in that standard, but have slightly different though related meanings. Some of the concurrency behavior of this command is left implementation-defined by the standard, so the above notes should be considered and compared with other implementations if necessary.

UNLISTEN

Name

UNLISTEN — stop listening for a notification

Synopsis

```
UNLISTEN { channel | * }
```

Description

UNLISTEN is used to remove an existing registration for NOTIFY events. UNLISTEN cancels any existing registration of the current PostgreSQL session as a listener on the notification channel named *channel*. The special wildcard * cancels all listener registrations for the current session.

NOTIFY contains a more extensive discussion of the use of LISTEN and NOTIFY.

Parameters

channel

Name of a notification channel (any identifier).

*

All current listen registrations for this session are cleared.

Notes

You can unlisten something you were not listening for; no warning or error will appear.

At the end of each session, UNLISTEN * is automatically executed.

A transaction that has executed UNLISTEN cannot be prepared for two-phase commit.

Examples

To make a registration:

```
LISTEN virtual;
NOTIFY virtual;
Asynchronous notification "virtual" received from server process with PID 8448.
```

Once UNLISTEN has been executed, further NOTIFY messages will be ignored:

```
UNLISTEN virtual;
NOTIFY virtual;
-- no NOTIFY event is received
```

Compatibility

There is no `UNLISTEN` command in the SQL standard.

See Also

LISTEN, NOTIFY

UPDATE

Name

UPDATE — update rows of a table

Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
UPDATE [ ONLY ] table_name [ * ] [ [ AS ] alias ]
    SET { column_name = { expression | DEFAULT } |
          ( column_name [, ...] ) = ( { expression | DEFAULT } [, ...] ) } [, ...]
    [ FROM from_list ]
    [ WHERE condition | WHERE CURRENT OF cursor_name ]
    [ RETURNING * | output_expression [ [ AS ] output_name ] [, ...] ]
```

Description

UPDATE changes the values of the specified columns in all rows that satisfy the condition. Only the columns to be modified need be mentioned in the SET clause; columns not explicitly modified retain their previous values.

There are two ways to modify a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the FROM clause. Which technique is more appropriate depends on the specific circumstances.

The optional RETURNING clause causes UPDATE to compute and return value(s) based on each row actually updated. Any expression using the table's columns, and/or columns of other tables mentioned in FROM, can be computed. The new (post-update) values of the table's columns are used. The syntax of the RETURNING list is identical to that of the output list of SELECT.

You must have the UPDATE privilege on the table, or at least on the column(s) that are listed to be updated. You must also have the SELECT privilege on any column whose values are read in the *expressions* or *condition*.

Parameters

with_query

The WITH clause allows you to specify one or more subqueries that can be referenced by name in the UPDATE query. See Section 7.8 and SELECT for details.

table_name

The name (optionally schema-qualified) of the table to update. If ONLY is specified before the table name, matching rows are updated in the named table only. If ONLY is not specified, matching rows are also updated in any tables inheriting from the named table. Optionally, * can be specified after the table name to explicitly indicate that descendant tables are included.

alias

A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `UPDATE foo AS f`, the remainder of the `UPDATE` statement must refer to this table as `f` not `foo`.

column_name

The name of a column in the table named by *table_name*. The column name can be qualified with a subfield name or array subscript, if needed. Do not include the table's name in the specification of a target column — for example, `UPDATE tab SET tab.col = 1` is invalid.

expression

An expression to assign to the column. The expression can use the old values of this and other columns in the table.

`DEFAULT`

Set the column to its default value (which will be NULL if no specific default expression has been assigned to it).

from_list

A list of table expressions, allowing columns from other tables to appear in the `WHERE` condition and the update expressions. This is similar to the list of tables that can be specified in the *FROM Clause* of a `SELECT` statement. Note that the target table must not appear in the *from_list*, unless you intend a self-join (in which case it must appear with an alias in the *from_list*).

condition

An expression that returns a value of type `boolean`. Only rows for which this expression returns `true` will be updated.

cursor_name

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be updated is the one most recently fetched from this cursor. The cursor must be a non-grouping query on the `UPDATE`'s target table. Note that `WHERE CURRENT OF` cannot be specified together with a Boolean condition. See DECLARE for more information about using cursors with `WHERE CURRENT OF`.

output_expression

An expression to be computed and returned by the `UPDATE` command after each row is updated. The expression can use any column names of the table named by *table_name* or table(s) listed in `FROM`. Write `*` to return all columns.

output_name

A name to use for a returned column.

Outputs

On successful completion, an `UPDATE` command returns a command tag of the form

`UPDATE` *count*

The *count* is the number of rows updated, including matched rows whose values did not change. Note that the number may be less than the number of rows that matched the *condition* when updates were suppressed by a `BEFORE UPDATE` trigger. If *count* is 0, no rows were updated by the query (this is not considered an error).

If the `UPDATE` command contains a `RETURNING` clause, the result will be similar to that of a `SELECT` statement containing the columns and values defined in the `RETURNING` list, computed over the row(s) updated by the command.

Notes

When a `FROM` clause is present, what essentially happens is that the target table is joined to the tables mentioned in the *`from_list`*, and each output row of the join represents an update operation for the target table. When using `FROM` you should ensure that the join produces at most one output row for each row to be modified. In other words, a target row shouldn't join to more than one row from the other table(s). If it does, then only one of the join rows will be used to update the target row, but which one will be used is not readily predictable.

Because of this indeterminacy, referencing other tables only within sub-selects is safer, though often harder to read and slower than using a join.

Examples

Change the word `Drama` to `Dramatic` in the column `kind` of the table `films`:

```
UPDATE films SET kind = 'Dramatic' WHERE kind = 'Drama';
```

Adjust temperature entries and reset precipitation to its default value in one row of the table `weather`:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp = DEFAULT
  WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Perform the same operation and return the updated entries:

```
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp = DEFAULT
  WHERE city = 'San Francisco' AND date = '2003-07-03'
  RETURNING temp_lo, temp_hi, prcp;
```

Use the alternative column-list syntax to do the same update:

```
UPDATE weather SET (temp_lo, temp_hi, prcp) = (temp_lo+1, temp_lo+15, DEFAULT)
  WHERE city = 'San Francisco' AND date = '2003-07-03';
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, using the `FROM` clause syntax:

```
UPDATE employees SET sales_count = sales_count + 1 FROM accounts
  WHERE accounts.name = 'Acme Corporation'
  AND employees.id = accounts.sales_person;
```

Perform the same operation, using a sub-select in the `WHERE` clause:

```
UPDATE employees SET sales_count = sales_count + 1 WHERE id =
  (SELECT sales_person FROM accounts WHERE name = 'Acme Corporation');
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. To do this without failing the entire transaction, use savepoints:

```
BEGIN;
-- other operations
SAVEPOINT sp1;
INSERT INTO wines VALUES('Chateau Lafite 2003', '24');
-- Assume the above fails because of a unique key violation,
-- so now we issue these commands:
ROLLBACK TO sp1;
UPDATE wines SET stock = stock + 24 WHERE winename = 'Chateau Lafite 2003';
-- continue with other operations, and eventually
COMMIT;
```

Change the `kind` column of the table `films` in the row on which the cursor `c_films` is currently positioned:

```
UPDATE films SET kind = 'Dramatic' WHERE CURRENT OF c_films;
```

Compatibility

This command conforms to the SQL standard, except that the `FROM` and `RETURNING` clauses are PostgreSQL extensions, as is the ability to use `WITH` with `UPDATE`.

According to the standard, the column-list syntax should allow a list of columns to be assigned from a single row-valued expression, such as a sub-select:

```
UPDATE accounts SET (contact_last_name, contact_first_name) =
    (SELECT last_name, first_name FROM salesmen
     WHERE salesmen.id = accounts.sales_id);
```

This is not currently implemented — the source must be a list of independent expressions.

Some other database systems offer a `FROM` option in which the target table is supposed to be listed again within `FROM`. That is not how PostgreSQL interprets `FROM`. Be careful when porting applications that use this extension.

VACUUM

Name

VACUUM — garbage-collect and optionally analyze a database

Synopsis

```
VACUUM [ ( { FULL | FREEZE | VERBOSE | ANALYZE } [, ...] ) ] [ table_name [ (column_name [
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] [ table_name ]
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] ANALYZE [ table_name [ (column_name [, ...] ) ] ]
```

Description

VACUUM reclaims storage occupied by dead tuples. In normal PostgreSQL operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present until a VACUUM is done. Therefore it's necessary to do VACUUM periodically, especially on frequently-updated tables.

With no parameter, VACUUM processes every table in the current database that the current user has permission to vacuum. With a parameter, VACUUM processes only that table.

VACUUM ANALYZE performs a VACUUM and then an ANALYZE for each selected table. This is a handy combination form for routine maintenance scripts. See ANALYZE for more details about its processing.

Plain VACUUM (without FULL) simply reclaims space and makes it available for re-use. This form of the command can operate in parallel with normal reading and writing of the table, as an exclusive lock is not obtained. However, extra space is not returned to the operating system (in most cases); it's just kept available for re-use within the same table. VACUUM FULL rewrites the entire contents of the table into a new disk file with no extra space, allowing unused space to be returned to the operating system. This form is much slower and requires an exclusive lock on each table while it is being processed.

When the option list is surrounded by parentheses, the options can be written in any order. Without parentheses, options must be specified in exactly the order shown above. The parenthesized syntax was added in PostgreSQL 9.0; the unparenthesized syntax is deprecated.

Parameters

FULL

Selects "full" vacuum, which can reclaim more space, but takes much longer and exclusively locks the table. This method also requires extra disk space, since it writes a new copy of the table and doesn't release the old copy until the operation is complete. Usually this should only be used when a significant amount of space needs to be reclaimed from within the table.

FREEZE

Selects aggressive "freezing" of tuples. Specifying FREEZE is equivalent to performing VACUUM with the vacuum_freeze_min_age and vacuum_freeze_table_age parameters set to zero. Aggressive freezing is always performed when the table is rewritten, so this option is redundant when FULL is specified.

`VERBOSE`

Prints a detailed vacuum activity report for each table.

`ANALYZE`

Updates statistics used by the planner to determine the most efficient way to execute a query.

`table_name`

The name (optionally schema-qualified) of a specific table to vacuum. Defaults to all tables in the current database.

`column_name`

The name of a specific column to analyze. Defaults to all columns. If a column list is specified, `ANALYZE` is implied.

Outputs

When `VERBOSE` is specified, `VACUUM` emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

Notes

To vacuum a table, one must ordinarily be the table's owner or a superuser. However, database owners are allowed to vacuum all tables in their databases, except shared catalogs. (The restriction for shared catalogs means that a true database-wide `VACUUM` can only be performed by a superuser.) `VACUUM` will skip over any tables that the calling user does not have permission to vacuum.

`VACUUM` cannot be executed inside a transaction block.

For tables with GIN indexes, `VACUUM` (in any form) also completes any pending index insertions, by moving pending index entries to the appropriate places in the main GIN index structure. See Section 58.4.1 for details.

We recommend that active production databases be vacuumed frequently (at least nightly), in order to remove dead rows. After adding or deleting a large number of rows, it might be a good idea to issue a `VACUUM ANALYZE` command for the affected table. This will update the system catalogs with the results of all recent changes, and allow the PostgreSQL query planner to make better choices in planning queries.

The `FULL` option is not recommended for routine use, but might be useful in special cases. An example is when you have deleted or updated most of the rows in a table and would like the table to physically shrink to occupy less disk space and allow faster table scans. `VACUUM FULL` will usually shrink the table more than a plain `VACUUM` would.

`VACUUM` causes a substantial increase in I/O traffic, which might cause poor performance for other active sessions. Therefore, it is sometimes advisable to use the cost-based vacuum delay feature. See Section 18.4.4 for details.

PostgreSQL includes an "autovacuum" facility which can automate routine vacuum maintenance. For more information about automatic and manual vacuuming, see Section 23.1.

Examples

The following is an example from running VACUUM on a table in the regression database:

```
regression=# VACUUM (VERBOSE, ANALYZE) onek;
INFO:  vacuuming "public.onek"
INFO:  index "onek_unique1" now contains 1000 tuples in 14 pages
DETAIL:  3000 index tuples were removed.
0 index pages have been deleted, 0 are currently reusable.
CPU 0.01s/0.08u sec elapsed 0.18 sec.
INFO:  index "onek_unique2" now contains 1000 tuples in 16 pages
DETAIL:  3000 index tuples were removed.
0 index pages have been deleted, 0 are currently reusable.
CPU 0.00s/0.07u sec elapsed 0.23 sec.
INFO:  index "onek_hundred" now contains 1000 tuples in 13 pages
DETAIL:  3000 index tuples were removed.
0 index pages have been deleted, 0 are currently reusable.
CPU 0.01s/0.08u sec elapsed 0.17 sec.
INFO:  index "onek_stringu1" now contains 1000 tuples in 48 pages
DETAIL:  3000 index tuples were removed.
0 index pages have been deleted, 0 are currently reusable.
CPU 0.01s/0.09u sec elapsed 0.59 sec.
INFO:  "onek": removed 3000 tuples in 108 pages
DETAIL:  CPU 0.01s/0.06u sec elapsed 0.07 sec.
INFO:  "onek": found 3000 removable, 1000 nonremovable tuples in 143 pages
DETAIL:  0 dead tuples cannot be removed yet.
There were 0 unused item pointers.
0 pages are entirely empty.
CPU 0.07s/0.39u sec elapsed 1.56 sec.
INFO:  analyzing "public.onek"
INFO:  "onek": 36 pages, 1000 rows sampled, 1000 estimated total rows
VACUUM
```

Compatibility

There is no VACUUM statement in the SQL standard.

See Also

vacuumdb, Section 18.4.4, Section 23.1.6

VALUES

Name

VALUES — compute a set of rows

Synopsis

```
VALUES ( expression [, ...] ) [, ...]
    [ ORDER BY sort_expression [ ASC | DESC | USING operator ] [, ...] ]
    [ LIMIT { count | ALL } ]
    [ OFFSET start [ ROW | ROWS ] ]
    [ FETCH { FIRST | NEXT } [ count ] { ROW | ROWS } ONLY ]
```

Description

VALUES computes a row value or set of row values specified by value expressions. It is most commonly used to generate a "constant table" within a larger command, but it can be used on its own.

When more than one row is specified, all the rows must have the same number of elements. The data types of the resulting table's columns are determined by combining the explicit or inferred types of the expressions appearing in that column, using the same rules as for UNION (see Section 10.5).

Within larger commands, VALUES is syntactically allowed anywhere that SELECT is. Because it is treated like a SELECT by the grammar, it is possible to use the ORDER BY, LIMIT (or equivalently FETCH FIRST), and OFFSET clauses with a VALUES command.

Parameters

expression

A constant or expression to compute and insert at the indicated place in the resulting table (set of rows). In a VALUES list appearing at the top level of an INSERT, an *expression* can be replaced by DEFAULT to indicate that the destination column's default value should be inserted. DEFAULT cannot be used when VALUES appears in other contexts.

sort_expression

An expression or integer constant indicating how to sort the result rows. This expression can refer to the columns of the VALUES result as column1, column2, etc. For more details see *ORDER BY Clause*.

operator

A sorting operator. For details see *ORDER BY Clause*.

count

The maximum number of rows to return. For details see *LIMIT Clause*.

start

The number of rows to skip before starting to return rows. For details see *LIMIT Clause*.

Notes

VALUES lists with very large numbers of rows should be avoided, as you might encounter out-of-memory failures or poor performance. VALUES appearing within INSERT is a special case (because the desired column types are known from the INSERT's target table, and need not be inferred by scanning the VALUES list), so it can handle larger lists than are practical in other contexts.

Examples

A bare VALUES command:

```
VALUES (1, 'one'), (2, 'two'), (3, 'three');
```

This will return a table of two columns and three rows. It's effectively equivalent to:

```
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

More usually, VALUES is used within a larger SQL command. The most common use is in INSERT:

```
INSERT INTO films (code, title, did, date_prod, kind)
    VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

In the context of INSERT, entries of a VALUES list can be DEFAULT to indicate that the column default should be used here instead of specifying a value:

```
INSERT INTO films VALUES
    ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes'),
    ('T_601', 'Yojimbo', 106, DEFAULT, 'Drama', DEFAULT);
```

VALUES can also be used where a sub-SELECT might be written, for example in a FROM clause:

```
SELECT f.*
  FROM films f, (VALUES('MGM', 'Horror'), ('UA', 'Sci-Fi')) AS t (studio, kind)
  WHERE f.studio = t.studio AND f.kind = t.kind;

UPDATE employees SET salary = salary * v.increase
  FROM (VALUES(1, 200000, 1.2), (2, 400000, 1.4)) AS v (depno, target, increase)
  WHERE employees.depno = v.depno AND employees.sales >= v.target;
```

Note that an AS clause is required when VALUES is used in a FROM clause, just as is true for SELECT. It is not required that the AS clause specify names for all the columns, but it's good practice to do so. (The default column names for VALUES are column1, column2, etc in PostgreSQL, but these names might be different in other database systems.)

When VALUES is used in INSERT, the values are all automatically coerced to the data type of the corresponding destination column. When it's used in other contexts, it might be necessary to specify the correct data type. If the entries are all quoted literal constants, coercing the first is sufficient to determine the assumed type for all:

```
SELECT * FROM machines
WHERE ip_address IN (VALUES('192.168.0.1'::inet), ('192.168.0.10'), ('192.168.1.43'));
```

> **Tip:** For simple `IN` tests, it's better to rely on the list-of-scalars form of `IN` than to write a `VALUES` query as shown above. The list of scalars method requires less writing and is often more efficient.

Compatibility

`VALUES` conforms to the SQL standard. `LIMIT` and `OFFSET` are PostgreSQL extensions; see also under SELECT.

See Also

INSERT, SELECT

II. PostgreSQL Client Applications

This part contains reference information for PostgreSQL client applications and utilities. Not all of these commands are of general utility; some might require special privileges. The common feature of these applications is that they can be run on any host, independent of where the database server resides.

When specified on the command line, user and database names have their case preserved — the presence of spaces or special characters might require quoting. Table names and other identifiers do not have their case preserved, except where documented, and might require quoting.

clusterdb

Name

`clusterdb` — cluster a PostgreSQL database

Synopsis

`clusterdb` [*connection-option*...] [`--verbose` | `-v`] [`--table` | `-t` *table*] ... [*dbname*]

`clusterdb` [*connection-option*...] [`--verbose` | `-v`] `--all` | `-a`

Description

clusterdb is a utility for reclustering tables in a PostgreSQL database. It finds tables that have previously been clustered, and clusters them again on the same index that was last used. Tables that have never been clustered are not affected.

clusterdb is a wrapper around the SQL command CLUSTER. There is no effective difference between clustering databases via this utility and via other methods for accessing the server.

Options

clusterdb accepts the following command-line arguments:

`-a`
`--all`

Cluster all databases.

`[-d]` *dbname*
`[--dbname=]`*dbname*

Specifies the name of the database to be clustered. If this is not specified and `-a` (or `--all`) is not used, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used.

`-e`
`--echo`

Echo the commands that clusterdb generates and sends to the server.

`-q`
`--quiet`

Do not display progress messages.

`-t` *table*
`--table=`*table*

Cluster *table* only. Multiple tables can be clustered by writing multiple `-t` switches.

`-v`
`--verbose`

Print detailed information during processing.

`-V`
`--version`

Print the clusterdb version and exit.

`-?`
`--help`

Show help about clusterdb command line arguments, and exit.

clusterdb also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force clusterdb to prompt for a password before connecting to a database.

This option is never essential, since clusterdb will automatically prompt for a password if the server demands password authentication. However, clusterdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=`*dbname*

Specifies the name of the database to connect to discover what other databases should be clustered. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see CLUSTER and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To cluster the database `test`:

```
$ clusterdb test
```

To cluster a single table `foo` in a database named `xyzzy`:

```
$ clusterdb --table foo xyzzy
```

See Also

CLUSTER

createdb

Name

createdb — create a new PostgreSQL database

Synopsis

createdb [*connection-option*...] [*option*...] [*dbname* [*description*]]

Description

createdb creates a new PostgreSQL database.

Normally, the database user who executes this command becomes the owner of the new database. However, a different owner can be specified via the -O option, if the executing user has appropriate privileges.

createdb is a wrapper around the SQL command CREATE DATABASE. There is no effective difference between creating databases via this utility and via other methods for accessing the server.

Options

createdb accepts the following command-line arguments:

dbname

Specifies the name of the database to be created. The name must be unique among all PostgreSQL databases in this cluster. The default is to create a database with the same name as the current system user.

description

Specifies a comment to be associated with the newly created database.

-D *tablespace*
--tablespace=*tablespace*

Specifies the default tablespace for the database. (This name is processed as a double-quoted identifier.)

-e
--echo

Echo the commands that createdb generates and sends to the server.

-E *encoding*
--encoding=*encoding*

Specifies the character encoding scheme to be used in this database. The character sets supported by the PostgreSQL server are described in Section 22.3.1.

`-l` *locale*
`--locale=`*locale*

Specifies the locale to be used in this database. This is equivalent to specifying both `--lc-collate` and `--lc-ctype`.

`--lc-collate=`*locale*

Specifies the LC_COLLATE setting to be used in this database.

`--lc-ctype=`*locale*

Specifies the LC_CTYPE setting to be used in this database.

`-O` *owner*
`--owner=`*owner*

Specifies the database user who will own the new database. (This name is processed as a double-quoted identifier.)

`-T` *template*
`--template=`*template*

Specifies the template database from which to build this database. (This name is processed as a double-quoted identifier.)

`-V`
`--version`

Print the createdb version and exit.

`-?`
`--help`

Show help about createdb command line arguments, and exit.

The options `-D`, `-l`, `-E`, `-O`, and `-T` correspond to options of the underlying SQL command CREATE DATABASE; see there for more information about them.

createdb also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or the local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force createdb to prompt for a password before connecting to a database.

This option is never essential, since createdb will automatically prompt for a password if the server demands password authentication. However, createdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=`*dbname*

Specifies the name of the database to connect to when creating the new database. If not specified, the `postgres` database will be used; if that does not exist (or if it is the name of the new database being created), `template1` will be used.

Environment

`PGDATABASE`

If set, the name of the database to create, unless overridden on the command line.

`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters. `PGUSER` also determines the name of the database to create, if it is not specified on the command line or by `PGDATABASE`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see CREATE DATABASE and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To create the database `demo` using the default database server:

```
$ createdb demo
```

To create the database `demo` using the server on host `eden`, port 5000, using the `LATIN1` encoding scheme with a look at the underlying command:

```
$ createdb -p 5000 -h eden -E LATIN1 -e demo
CREATE DATABASE demo ENCODING 'LATIN1';
```

See Also

dropdb, CREATE DATABASE

createlang

Name

`createlang` — install a PostgreSQL procedural language

Synopsis

`createlang` [*connection-option*...] *langname* [*dbname*]

`createlang` [*connection-option*...] `--list` | `-l` [*dbname*]

Description

createlang is a utility for adding a procedural language to a PostgreSQL database.

createlang is just a wrapper around the CREATE EXTENSION SQL command.

> **Caution**
>
> createlang is deprecated and may be removed in a future PostgreSQL release. Direct use of the `CREATE EXTENSION` command is recommended instead.

Options

createlang accepts the following command-line arguments:

langname

Specifies the name of the procedural language to be installed. (This name is lower-cased.)

`[-d]` *dbname*
`[--dbname=]`*dbname*

Specifies the database to which the language should be added. The default is to use the database with the same name as the current system user.

`-e`
`--echo`

Display SQL commands as they are executed.

`-l`
`--list`

Show a list of already installed languages in the target database.

`-V`
`--version`

Print the createlang version and exit.

`-?`
`--help`

Show help about createlang command line arguments, and exit.

createlang also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force createlang to prompt for a password before connecting to a database.

This option is never essential, since createlang will automatically prompt for a password if the server demands password authentication. However, createlang will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

Most error messages are self-explanatory. If not, run createlang with the `--echo` option and see the respective SQL command for details. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

Use droplang to remove a language.

Examples

To install the language `pltcl` into the database `template1`:

```
$ createlang pltcl template1
```

Note that installing the language into `template1` will cause it to be automatically installed into subsequently-created databases as well.

See Also

droplang, CREATE EXTENSION, CREATE LANGUAGE

createuser

Name

`createuser` — define a new PostgreSQL user account

Synopsis

`createuser` [*connection-option*...] [*option*...] [*username*]

Description

createuser creates a new PostgreSQL user (or more precisely, a role). Only superusers and users with `CREATEROLE` privilege can create new users, so createuser must be invoked by someone who can connect as a superuser or a user with `CREATEROLE` privilege.

If you wish to create a new superuser, you must connect as a superuser, not merely with `CREATEROLE` privilege. Being a superuser implies the ability to bypass all access permission checks within the database, so superuserdom should not be granted lightly.

createuser is a wrapper around the SQL command CREATE ROLE. There is no effective difference between creating users via this utility and via other methods for accessing the server.

Options

createuser accepts the following command-line arguments:

username

Specifies the name of the PostgreSQL user to be created. This name must be different from all existing roles in this PostgreSQL installation.

`-c` *number*
`--connection-limit=`*number*

Set a maximum number of connections for the new user. The default is to set no limit.

`-d`
`--createdb`

The new user will be allowed to create databases.

`-D`
`--no-createdb`

The new user will not be allowed to create databases. This is the default.

`-e`
`--echo`

Echo the commands that createuser generates and sends to the server.

`-E`
`--encrypted`

Encrypts the user's password stored in the database. If not specified, the default password behavior is used.

`-g` *role*
`--role=`*role*

Indicates role to which this role will be added immediately as a new member. Multiple roles to which this role will be added as a member can be specified by writing multiple `-g` switches.

`-i`
`--inherit`

The new role will automatically inherit privileges of roles it is a member of. This is the default.

`-I`
`--no-inherit`

The new role will not automatically inherit privileges of roles it is a member of.

`--interactive`

Prompt for the user name if none is specified on the command line, and also prompt for whichever of the options `-d`/`-D`, `-r`/`-R`, `-s`/`-S` is not specified on the command line. (This was the default behavior up to PostgreSQL 9.1.)

`-l`
`--login`

The new user will be allowed to log in (that is, the user name can be used as the initial session user identifier). This is the default.

`-L`
`--no-login`

The new user will not be allowed to log in. (A role without login privilege is still useful as a means of managing database permissions.)

`-N`
`--unencrypted`

Does not encrypt the user's password stored in the database. If not specified, the default password behavior is used.

`-P`
`--pwprompt`

If given, createuser will issue a prompt for the password of the new user. This is not necessary if you do not plan on using password authentication.

`-r`
`--createrole`

The new user will be allowed to create new roles (that is, this user will have `CREATEROLE` privilege).

`-R`
`--no-createrole`

The new user will not be allowed to create new roles. This is the default.

`-s`
`--superuser`

The new user will be a superuser.

`-S`
`--no-superuser`

The new user will not be a superuser. This is the default.

`-V`
`--version`

Print the createuser version and exit.

`--replication`

The new user will have the `REPLICATION` privilege, which is described more fully in the documentation for CREATE ROLE.

`--no-replication`

The new user will not have the `REPLICATION` privilege, which is described more fully in the documentation for CREATE ROLE.

`-?`
`--help`

Show help about createuser command line arguments, and exit.

createuser also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as (not the user name to create).

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force createuser to prompt for a password (for connecting to the server, not for the password of the new user).

This option is never essential, since createuser will automatically prompt for a password if the server demands password authentication. However, createuser will waste a connection attempt

finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see CREATE ROLE and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To create a user `joe` on the default database server:

```
$ createuser joe
```

To create a user `joe` on the default database server with prompting for some additional attributes:

```
$ createuser --interactive joe
Shall the new role be a superuser? (y/n) n
Shall the new role be allowed to create databases? (y/n) n
Shall the new role be allowed to create more new roles? (y/n) n
```

To create the same user `joe` using the server on host `eden`, port 5000, with attributes explicitly specified, taking a look at the underlying command:

```
$ createuser -h eden -p 5000 -S -D -R -e joe
CREATE ROLE joe NOSUPERUSER NOCREATEDB NOCREATEROLE INHERIT LOGIN;
```

To create the user `joe` as a superuser, and assign a password immediately:

```
$ createuser -P -s -e joe
Enter password for new role: xyzzy
Enter it again: xyzzy
CREATE ROLE joe PASSWORD 'md5b5f5ba1a423792b526f799ae4eb3d59e' SUPERUSER CREATEDB CREATEROLE INHER
```

In the above example, the new password isn't actually echoed when typed, but we show what was typed for clarity. As you see, the password is encrypted before it is sent to the client. If the option `--unencrypted` is used, the password *will* appear in the echoed command (and possibly also in the server log and elsewhere), so you don't want to use `-e` in that case, if anyone else can see your screen.

See Also

dropuser, CREATE ROLE

dropdb

Name

`dropdb` — remove a PostgreSQL database

Synopsis

`dropdb` [*`connection-option`*...] [*`option`*...] *`dbname`*

Description

dropdb destroys an existing PostgreSQL database. The user who executes this command must be a database superuser or the owner of the database.

dropdb is a wrapper around the SQL command DROP DATABASE. There is no effective difference between dropping databases via this utility and via other methods for accessing the server.

Options

dropdb accepts the following command-line arguments:

`dbname`

Specifies the name of the database to be removed.

`-e`
`--echo`

Echo the commands that dropdb generates and sends to the server.

`-i`
`--interactive`

Issues a verification prompt before doing anything destructive.

`-V`
`--version`

Print the dropdb version and exit.

`--if-exists`

Do not throw an error if the database does not exist. A notice is issued in this case.

`-?`
`--help`

Show help about dropdb command line arguments, and exit.

dropdb also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force dropdb to prompt for a password before connecting to a database.

This option is never essential, since dropdb will automatically prompt for a password if the server demands password authentication. However, dropdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=`*dbname*

Specifies the name of the database to connect to in order to drop the target database. If not specified, the `postgres` database will be used; if that does not exist (or is the database being dropped), `template1` will be used.

Environment

`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see DROP DATABASE and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To destroy the database `demo` on the default database server:

```
$ dropdb demo
```

To destroy the database `demo` using the server on host `eden`, port 5000, with verification and a peek at the underlying command:

```
$ dropdb -p 5000 -h eden -i -e demo
Database "demo" will be permanently deleted.
Are you sure? (y/n) y
DROP DATABASE demo;
```

See Also

createdb, DROP DATABASE

droplang

Name

`droplang` — remove a PostgreSQL procedural language

Synopsis

`droplang` [*connection-option*...] *langname* [*dbname*]

`droplang` [*connection-option*...] `--list` | `-l` [*dbname*]

Description

droplang is a utility for removing an existing procedural language from a PostgreSQL database.

droplang is just a wrapper around the DROP EXTENSION SQL command.

> **Caution**
>
> droplang is deprecated and may be removed in a future PostgreSQL release. Direct use of the `DROP EXTENSION` command is recommended instead.

Options

droplang accepts the following command line arguments:

langname

Specifies the name of the procedural language to be removed. (This name is lower-cased.)

`[-d]` *dbname*
`[--dbname=]`*dbname*

Specifies from which database the language should be removed. The default is to use the database with the same name as the current system user.

`-e`
`--echo`

Display SQL commands as they are executed.

`-l`
`--list`

Show a list of already installed languages in the target database.

`-V`
`--version`

Print the droplang version and exit.

`-?`
`--help`

Show help about droplang command line arguments, and exit.

droplang also accepts the following command line arguments for connection parameters:

`-h` *`host`*
`--host=`*`host`*

Specifies the host name of the machine on which the server is running. If host begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *`port`*
`--port=`*`port`*

Specifies the Internet TCP/IP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *`username`*
`--username=`*`username`*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force droplang to prompt for a password before connecting to a database.

This option is never essential, since droplang will automatically prompt for a password if the server demands password authentication. However, droplang will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

Most error messages are self-explanatory. If not, run droplang with the `--echo` option and see under the respective SQL command for details. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

Use createlang to add a language.

Examples

To remove the language `pltcl`:

```
$ droplang pltcl dbname
```

See Also

createlang, DROP EXTENSION, DROP LANGUAGE

dropuser

Name

dropuser — remove a PostgreSQL user account

Synopsis

dropuser [*connection-option*...] [*option*...] [*username*]

Description

dropuser removes an existing PostgreSQL user. Only superusers and users with the CREATEROLE privilege can remove PostgreSQL users. (To remove a superuser, you must yourself be a superuser.)

dropuser is a wrapper around the SQL command DROP ROLE. There is no effective difference between dropping users via this utility and via other methods for accessing the server.

Options

dropuser accepts the following command-line arguments:

username

Specifies the name of the PostgreSQL user to be removed. You will be prompted for a name if none is specified on the command line and the -i/--interactive option is used.

-e
--echo

Echo the commands that dropuser generates and sends to the server.

-i
--interactive

Prompt for confirmation before actually removing the user, and prompt for the user name if none is specified on the command line.

-V
--version

Print the dropuser version and exit.

--if-exists

Do not throw an error if the user does not exist. A notice is issued in this case.

-?
--help

Show help about dropuser command line arguments, and exit.

dropuser also accepts the following command-line arguments for connection parameters:

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as (not the user name to drop).

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force dropuser to prompt for a password before connecting to a database.

This option is never essential, since dropuser will automatically prompt for a password if the server demands password authentication. However, dropuser will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Environment

`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see DROP ROLE and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Examples

To remove user `joe` from the default database server:

```
$ dropuser joe
```

To remove user `joe` using the server on host `eden`, port 5000, with verification and a peek at the underlying command:

```
$ dropuser -p 5000 -h eden -i -e joe
Role "joe" will be permanently removed.
Are you sure? (y/n) y
DROP ROLE joe;
```

See Also

createuser, DROP ROLE

ecpg

Name

ecpg — embedded SQL C preprocessor

Synopsis

ecpg [*option*...] *file*...

Description

ecpg is the embedded SQL preprocessor for C programs. It converts C programs with embedded SQL statements to normal C code by replacing the SQL invocations with special function calls. The output files can then be processed with any C compiler tool chain.

ecpg will convert each input file given on the command line to the corresponding C output file. Input files preferably have the extension .pgc, in which case the extension will be replaced by .c to determine the output file name. If the extension of the input file is not .pgc, then the output file name is computed by appending .c to the full file name. The output file name can also be overridden using the -o option.

This reference page does not describe the embedded SQL language. See Chapter 33 for more information on that topic.

Options

ecpg accepts the following command-line arguments:

-c

Automatically generate certain C code from SQL code. Currently, this works for EXEC SQL TYPE.

-C *mode*

Set a compatibility mode. *mode* can be INFORMIX or INFORMIX_SE.

-D *symbol*

Define a C preprocessor symbol.

-i

Parse system include files as well.

-I *directory*

Specify an additional include path, used to find files included via EXEC SQL INCLUDE. Defaults are . (current directory), /usr/local/include, the PostgreSQL include directory which is defined at compile time (default: /usr/local/pgsql/include), and /usr/include, in that order.

`-o` *`filename`*

Specifies that `ecpg` should write all its output to the given *`filename`*.

`-r` *`option`*

Selects run-time behavior. *`Option`* can be one of the following:

`no_indicator`

Do not use indicators but instead use special values to represent null values. Historically there have been databases using this approach.

`prepare`

Prepare all statements before using them. Libecpg will keep a cache of prepared statements and reuse a statement if it gets executed again. If the cache runs full, libecpg will free the least used statement.

`questionmarks`

Allow question mark as placeholder for compatibility reasons. This used to be the default long ago.

`-t`

Turn on autocommit of transactions. In this mode, each SQL command is automatically committed unless it is inside an explicit transaction block. In the default mode, commands are committed only when `EXEC SQL COMMIT` is issued.

`-v`

Print additional information including the version and the "include" path.

`--version`

Print the ecpg version and exit.

`-?`
`--help`

Show help about ecpg command line arguments, and exit.

Notes

When compiling the preprocessed C code files, the compiler needs to be able to find the ECPG header files in the PostgreSQL include directory. Therefore, you might have to use the `-I` option when invoking the compiler (e.g., `-I/usr/local/pgsql/include`).

Programs using C code with embedded SQL have to be linked against the `libecpg` library, for example using the linker options `-L/usr/local/pgsql/lib -lecpg`.

The value of either of these directories that is appropriate for the installation can be found out using pg_config.

Examples

If you have an embedded SQL C source file named `prog1.pgc`, you can create an executable program using the following sequence of commands:

```
ecpg prog1.pgc
cc -I/usr/local/pgsql/include -c prog1.c
cc -o prog1 prog1.o -L/usr/local/pgsql/lib -lecpg
```

pg_basebackup

Name

pg_basebackup — take a base backup of a PostgreSQL cluster

Synopsis

pg_basebackup [*option*...]

Description

pg_basebackup is used to take base backups of a running PostgreSQL database cluster. These are taken without affecting other clients to the database, and can be used both for point-in-time recovery (see Section 24.3) and as the starting point for a log shipping or streaming replication standby servers (see Section 25.2).

pg_basebackup makes a binary copy of the database cluster files, while making sure the system is put in and out of backup mode automatically. Backups are always taken of the entire database cluster; it is not possible to back up individual databases or database objects. For individual database backups, a tool such as pg_dump must be used.

The backup is made over a regular PostgreSQL connection, and uses the replication protocol. The connection must be made with a superuser or a user having REPLICATION permissions (see Section 20.2), and pg_hba.conf must explicitly permit the replication connection. The server must also be configured with max_wal_senders set high enough to leave at least one session available for the backup.

There can be multiple pg_basebackups running at the same time, but it is better from a performance point of view to take only one backup, and copy the result.

pg_basebackup can make a base backup from not only the master but also the standby. To take a backup from the standby, set up the standby so that it can accept replication connections (that is, set max_wal_senders and hot_standby, and configure host-based authentication). You will also need to enable full_page_writes on the master.

Note that there are some limitations in an online backup from the standby:

- The backup history file is not created in the database cluster backed up.
- There is no guarantee that all WAL files required for the backup are archived at the end of backup. If you are planning to use the backup for an archive recovery and want to ensure that all required files are available at that moment, you need to include them into the backup by using -x option.
- If the standby is promoted to the master during online backup, the backup fails.
- All WAL records required for the backup must contain sufficient full-page writes, which requires you to enable full_page_writes on the master and not to use a tool like pg_compresslog as archive_command to remove full-page writes from WAL files.

Options

The following command-line options control the location and format of the output.

`-D` *directory*
`--pgdata=`*directory*

Directory to write the output to. pg_basebackup will create the directory and any parent directories if necessary. The directory may already exist, but it is an error if the directory already exists and is not empty.

When the backup is in tar mode, and the directory is specified as `-` (dash), the tar file will be written to `stdout`.

This option is required.

`-F` *format*
`--format=`*format*

Selects the format for the output. *format* can be one of the following:

`p`
`plain`

Write the output as plain files, with the same layout as the current data directory and tablespaces. When the cluster has no additional tablespaces, the whole database will be placed in the target directory. If the cluster contains additional tablespaces, the main data directory will be placed in the target directory, but all other tablespaces will be placed in the same absolute path as they have on the server.

This is the default format.

`t`
`tar`

Write the output as tar files in the target directory. The main data directory will be written to a file named `base.tar`, and all other tablespaces will be named after the tablespace OID.

If the value `-` (dash) is specified as target directory, the tar contents will be written to standard output, suitable for piping to for example gzip. This is only possible if the cluster has no additional tablespaces.

`-r` *rate*
`--max-rate=`*rate*

The maximum transfer rate of data transferred from the server. Values are in kilobytes per second. Use a suffix of `M` to indicate megabytes per second. A suffix of `k` is also accepted, and has no effect. Valid values are between 32 kilobytes per second and 1024 megabytes per second.

The purpose is to limit the impact of pg_basebackup on the running server.

This option always affects transfer of the data directory. Transfer of WAL files is only affected if the collection method is `fetch`.

`-R`
`--write-recovery-conf`

Write a minimal `recovery.conf` in the output directory (or into the base archive file when using tar format) to ease setting up a standby server.

`-T` *olddir*`=`*newdir*
`--tablespace-mapping=`*olddir*`=`*newdir*

Relocate the tablespace in directory *olddir* to *newdir* during the backup. To be effective, *olddir* must exactly match the path specification of the tablespace as it is currently defined. (But it is not an error if there is no tablespace in *olddir* contained in the backup.) Both *olddir* and *newdir* must be absolute paths. If a path happens to contain a = sign, escape it with a backslash. This option can be specified multiple times for multiple tablespaces. See examples below.

If a tablespace is relocated in this way, the symbolic links inside the main data directory are updated to point to the new location. So the new data directory is ready to be used for a new server instance with all tablespaces in the updated locations.

`--xlogdir=`*xlogdir*

Specifies the location for the transaction log directory. *xlogdir* must be an absolute path. The transaction log directory can only be specified when the backup is in plain mode.

`-x`
`--xlog`

Using this option is equivalent of using `-X` with method `fetch`.

`-X` *method*
`--xlog-method=`*method*

Includes the required transaction log files (WAL files) in the backup. This will include all transaction logs generated during the backup. If this option is specified, it is possible to start a postmaster directly in the extracted directory without the need to consult the log archive, thus making this a completely standalone backup.

The following methods for collecting the transaction logs are supported:

`f`
`fetch`

The transaction log files are collected at the end of the backup. Therefore, it is necessary for the wal_keep_segments parameter to be set high enough that the log is not removed before the end of the backup. If the log has been rotated when it's time to transfer it, the backup will fail and be unusable.

`s`
`stream`

Stream the transaction log while the backup is created. This will open a second connection to the server and start streaming the transaction log in parallel while running the backup. Therefore, it will use up two slots configured by the max_wal_senders parameter. As long as the client can keep up with transaction log received, using this mode requires no extra transaction logs to be saved on the master.

`-z`
`--gzip`

Enables gzip compression of tar file output, with the default compression level. Compression is only available when using the tar format.

`-Z` *level*
`--compress=`*level*

Enables gzip compression of tar file output, and specifies the compression level (1 through 9, 9 being best compression). Compression is only available when using the tar format.

The following command-line options control the generation of the backup and the running of the program.

`-c` *fast|spread*
`--checkpoint=`*fast|spread*

Sets checkpoint mode to fast or spread (default) (see Section 24.3.3).

`-l` *label*
`--label=`*label*

Sets the label for the backup. If none is specified, a default value of "`pg_basebackup base backup`" will be used.

`-P`
`--progress`

Enables progress reporting. Turning this on will deliver an approximate progress report during the backup. Since the database may change during the backup, this is only an approximation and may not end at exactly `100%`. In particular, when WAL log is included in the backup, the total amount of data cannot be estimated in advance, and in this case the estimated target size will increase once it passes the total estimate without WAL.

When this is enabled, the backup will start by enumerating the size of the entire database, and then go back and send the actual contents. This may make the backup take slightly longer, and in particular it will take longer before the first data is sent.

`-v`
`--verbose`

Enables verbose mode. Will output some extra steps during startup and shutdown, as well as show the exact file name that is currently being processed if progress reporting is also enabled.

The following command-line options control the database connection parameters.

`-d` *connstr*
`--dbname=`*connstr*

Specifies parameters used to connect to the server, as a connection string. See Section 31.1.1 for more information.

The option is called `--dbname` for consistency with other client applications, but because pg_basebackup doesn't connect to any particular database in the cluster, database name in the connection string will be ignored.

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-s` *interval*
`--status-interval=`*interval*

Specifies the number of seconds between status packets sent back to the server. This allows for easier monitoring of the progress from server. A value of zero disables the periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout disconnect. The default value is 10 seconds.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_basebackup to prompt for a password before connecting to a database.

This option is never essential, since pg_basebackup will automatically prompt for a password if the server demands password authentication. However, pg_basebackup will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Other options are also available:

`-V`
`--version`

Print the pg_basebackup version and exit.

`-?`
`--help`

Show help about pg_basebackup command line arguments, and exit.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by libpq (see Section 31.14).

Notes

The backup will include all files in the data directory and tablespaces, including the configuration files and any additional files placed in the directory by third parties. But only regular files and directories are copied. Symbolic links (other than those used for tablespaces) and special device files are skipped. (See Section 49.3 for the precise details.)

Tablespaces will in plain format by default be backed up to the same path they have on the server, unless the option `--tablespace-mapping` is used. Without this option, running a plain format base backup on the same host as the server will not work if tablespaces are in use, because the backup would have to be written to the same directory locations as the original tablespaces.

pg_basebackup works with servers of the same or an older major version, down to 9.1. However, WAL streaming mode (-X stream) only works with server version 9.3 and later.

Examples

To create a base backup of the server at `mydbserver` and store it in the local directory `/usr/local/pgsql/data`:

```
$ pg_basebackup -h mydbserver -D /usr/local/pgsql/data
```

To create a backup of the local server with one compressed tar file for each tablespace, and store it in the directory `backup`, showing a progress report while running:

```
$ pg_basebackup -D backup -Ft -z -P
```

To create a backup of a single-tablespace local database and compress this with bzip2:

```
$ pg_basebackup -D - -Ft | bzip2 > backup.tar.bz2
```

(This command will fail if there are multiple tablespaces in the database.)

To create a backup of a local database where the tablespace in `/opt/ts` is relocated to `./backup/ts`:

```
$ pg_basebackup -D backup/data -T /opt/ts=$(pwd)/backup/ts
```

See Also

pg_dump

pg_config

Name

pg_config — retrieve information about the installed version of PostgreSQL

Synopsis

pg_config [*option*...]

Description

The pg_config utility prints configuration parameters of the currently installed version of PostgreSQL. It is intended, for example, to be used by software packages that want to interface to PostgreSQL to facilitate finding the required header files and libraries.

Options

To use pg_config, supply one or more of the following options:

--bindir

Print the location of user executables. Use this, for example, to find the psql program. This is normally also the location where the pg_config program resides.

--docdir

Print the location of documentation files.

--htmldir

Print the location of HTML documentation files.

--includedir

Print the location of C header files of the client interfaces.

--pkgincludedir

Print the location of other C header files.

--includedir-server

Print the location of C header files for server programming.

--libdir

Print the location of object code libraries.

--pkglibdir

Print the location of dynamically loadable modules, or where the server would search for them. (Other architecture-dependent data files might also be installed in this directory.)

--localedir

Print the location of locale support files. (This will be an empty string if locale support was not configured when PostgreSQL was built.)

`--mandir`

Print the location of manual pages.

`--sharedir`

Print the location of architecture-independent support files.

`--sysconfdir`

Print the location of system-wide configuration files.

`--pgxs`

Print the location of extension makefiles.

`--configure`

Print the options that were given to the `configure` script when PostgreSQL was configured for building. This can be used to reproduce the identical configuration, or to find out with what options a binary package was built. (Note however that binary packages often contain vendor-specific custom patches.) See also the examples below.

`--cc`

Print the value of the `CC` variable that was used for building PostgreSQL. This shows the C compiler used.

`--cppflags`

Print the value of the `CPPFLAGS` variable that was used for building PostgreSQL. This shows C compiler switches needed at preprocessing time (typically, `-I` switches).

`--cflags`

Print the value of the `CFLAGS` variable that was used for building PostgreSQL. This shows C compiler switches.

`--cflags_sl`

Print the value of the `CFLAGS_SL` variable that was used for building PostgreSQL. This shows extra C compiler switches used for building shared libraries.

`--ldflags`

Print the value of the `LDFLAGS` variable that was used for building PostgreSQL. This shows linker switches.

`--ldflags_ex`

Print the value of the `LDFLAGS_EX` variable that was used for building PostgreSQL. This shows linker switches used for building executables only.

`--ldflags_sl`

Print the value of the `LDFLAGS_SL` variable that was used for building PostgreSQL. This shows linker switches used for building shared libraries only.

`--libs`

Print the value of the `LIBS` variable that was used for building PostgreSQL. This normally contains `-l` switches for external libraries linked into PostgreSQL.

`--version`

Print the version of PostgreSQL.

`-?`
`--help`

Show help about pg_config command line arguments, and exit.

If more than one option is given, the information is printed in that order, one item per line. If no options are given, all available information is printed, with labels.

Notes

The options `--docdir`, `--pkgincludedir`, `--localedir`, `--mandir`, `--sharedir`, `--sysconfdir`, `--cc`, `--cppflags`, `--cflags`, `--cflags_sl`, `--ldflags`, `--ldflags_sl`, and `--libs` were added in PostgreSQL 8.1. The option `--htmldir` was added in PostgreSQL 8.4. The option `--ldflags_ex` was added in PostgreSQL 9.0.

Example

To reproduce the build configuration of the current PostgreSQL installation, run the following command:

```
eval ./configure `pg_config --configure`
```

The output of `pg_config --configure` contains shell quotation marks so arguments with spaces are represented correctly. Therefore, using `eval` is required for proper results.

pg_dump

Name

pg_dump — extract a PostgreSQL database into a script file or other archive file

Synopsis

pg_dump [*connection-option*...] [*option*...] [*dbname*]

Description

pg_dump is a utility for backing up a PostgreSQL database. It makes consistent backups even if the database is being used concurrently. pg_dump does not block other users accessing the database (readers or writers).

Dumps can be output in script or archive file formats. Script dumps are plain-text files containing the SQL commands required to reconstruct the database to the state it was in at the time it was saved. To restore from such a script, feed it to psql. Script files can be used to reconstruct the database even on other machines and other architectures; with some modifications, even on other SQL database products.

The alternative archive file formats must be used with pg_restore to rebuild the database. They allow pg_restore to be selective about what is restored, or even to reorder the items prior to being restored. The archive file formats are designed to be portable across architectures.

When used with one of the archive file formats and combined with pg_restore, pg_dump provides a flexible archival and transfer mechanism. pg_dump can be used to backup an entire database, then pg_restore can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file formats are the "custom" format (`-Fc`) and the "directory" format(`-Fd`). They allow for selection and reordering of all archived items, support parallel restoration, and are compressed by default. The "directory" format is the only format that supports parallel dumps.

While running pg_dump, one should examine the output for any warnings (printed on standard error), especially in light of the limitations listed below.

Options

The following command-line options control the content and format of the output.

dbname

Specifies the name of the database to be dumped. If this is not specified, the environment variable PGDATABASE is used. If that is not set, the user name specified for the connection is used.

`-a`
`--data-only`

Dump only the data, not the schema (data definitions). Table data, large objects, and sequence values are dumped.

This option is similar to, but for historical reasons not identical to, specifying `--section=data`.

`-b`
`--blobs`

Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified, so the `-b` switch is only useful to add large objects to selective dumps.

`-c`
`--clean`

Output commands to clean (drop) database objects prior to outputting the commands for creating them. (Unless `--if-exists` is also specified, restore might generate some harmless error messages, if any objects were not present in the destination database.)

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-C`
`--create`

Begin the output with a command to create the database itself and reconnect to the created database. (With a script of this form, it doesn't matter which database in the destination installation you connect to before running the script.) If `--clean` is also specified, the script drops and recreates the target database before reconnecting to it.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-E` *`encoding`*
`--encoding=`*`encoding`*

Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `PGCLIENTENCODING` environment variable to the desired dump encoding.)

`-f` *`file`*
`--file=`*`file`*

Send output to the specified file. This parameter can be omitted for file based output formats, in which case the standard output is used. It must be given for the directory output format however, where it specifies the target directory instead of a file. In this case the directory is created by `pg_dump` and must not exist before.

`-F` *`format`*
`--format=`*`format`*

Selects the format of the output. *`format`* can be one of the following:

`p`
`plain`

Output a plain-text SQL script file (the default).

`c`
`custom`

Output a custom-format archive suitable for input into pg_restore. Together with the directory output format, this is the most flexible output format in that it allows manual selection and reordering of archived items during restore. This format is also compressed by default.

`d`
`directory`

Output a directory-format archive suitable for input into pg_restore. This will create a directory with one file for each table and blob being dumped, plus a so-called Table of Contents file describing the dumped objects in a machine-readable format that pg_restore can read. A directory format archive can be manipulated with standard Unix tools; for example, files in an uncompressed archive can be compressed with the gzip tool. This format is compressed by default and also supports parallel dumps.

`t`
`tar`

Output a `tar`-format archive suitable for input into pg_restore. The tar-format is compatible with the directory-format; extracting a tar-format archive produces a valid directory-format archive. However, the tar-format does not support compression and has a limit of 8 GB on the size of individual tables. Also, the relative order of table data items cannot be changed during restore.

`-i`
`--ignore-version`

A deprecated option that is now ignored.

`-j` *`njobs`*
`--jobs=`*`njobs`*

Run the dump in parallel by dumping *`njobs`* tables simultaneously. This option reduces the time of the dump but it also increases the load on the database server. You can only use this option with the directory output format because this is the only output format where multiple processes can write their data at the same time.

pg_dump will open *`njobs`* + 1 connections to the database, so make sure your max_connections setting is high enough to accommodate all connections.

Requesting exclusive locks on database objects while running a parallel dump could cause the dump to fail. The reason is that the pg_dump master process requests shared locks on the objects that the worker processes are going to dump later in order to make sure that nobody deletes them and makes them go away while the dump is running. If another client then requests an exclusive lock on a table, that lock will not be granted but will be queued waiting for the shared lock of the master process to be released. Consequently any other access to the table will not be granted either and will queue after the exclusive lock request. This includes the worker process trying to dump the table. Without any precautions this would be a classic deadlock situation. To detect this conflict, the pg_dump worker process requests another shared lock using the `NOWAIT` option. If the worker process is not granted this shared lock, somebody else must have requested an exclusive lock in the meantime and there is no way to continue with the dump, so pg_dump has no choice but to abort the dump.

For a consistent backup, the database server needs to support synchronized snapshots, a feature that was introduced in PostgreSQL 9.2. With this feature, database clients can ensure they see the same data set even though they use different connections. `pg_dump -j` uses multiple database connections; it connects to the database once with the master process and once again for each worker job. Without the synchronized snapshot feature, the different worker jobs wouldn't be guaranteed to see the same data in each connection, which could lead to an inconsistent backup.

If you want to run a parallel dump of a pre-9.2 server, you need to make sure that the database content doesn't change from between the time the master connects to the database until the last

worker job has connected to the database. The easiest way to do this is to halt any data modifying processes (DDL and DML) accessing the database before starting the backup. You also need to specify the `--no-synchronized-snapshots` parameter when running `pg_dump -j` against a pre-9.2 PostgreSQL server.

`-n` *schema*
`--schema=`*schema*

Dump only schemas matching *schema*; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. Also, the *schema* parameter is interpreted as a pattern according to the same rules used by psql's `\d` commands (see *Patterns*), so multiple schemas can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see *Examples*.

Note: When `-n` is specified, pg_dump makes no attempt to dump any other database objects that the selected schema(s) might depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

Note: Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.

`-N` *schema*
`--exclude-schema=`*schema*

Do not dump any schemas matching the *schema* pattern. The pattern is interpreted according to the same rules as for `-n`. `-N` can be given more than once to exclude schemas matching any of several patterns.

When both `-n` and `-N` are given, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

`-o`
`--oids`

Dump object identifiers (OIDs) as part of the data for every table. Use this option if your application references the OID columns in some way (e.g., in a foreign key constraint). Otherwise, this option should not be used.

`-O`
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, pg_dump issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`-R`
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`
`--schema-only`

Dump only the object definitions (schema), not data.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data --section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word "schema" in a different meaning.)

To exclude table data for only a subset of tables in the database, see `--exclude-table-data`.

`-S` *username*
`--superuser=`*username*

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

`-t` *table*
`--table=`*table*

Dump only tables (or views or sequences or foreign tables) matching *table*. Multiple tables can be selected by writing multiple `-t` switches. Also, the *table* parameter is interpreted as a pattern according to the same rules used by psql's `\d` commands (see *Patterns*), so multiple tables can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards; see *Examples*.

The `-n` and `-N` switches have no effect when `-t` is used, because tables selected by `-t` will be dumped regardless of those switches, and non-table objects will not be dumped.

> **Note:** When `-t` is specified, pg_dump makes no attempt to dump any other database objects that the selected table(s) might depend upon. Therefore, there is no guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

> **Note:** The behavior of the `-t` switch is not entirely upward compatible with pre-8.2 PostgreSQL versions. Formerly, writing `-t tab` would dump all tables named `tab`, but now it just dumps whichever one is visible in your default search path. To get the old behavior you can write `-t '*.tab'`. Also, you must write something like `-t sch.tab` to select a table in a particular schema, rather than the old locution of `-n sch -t tab`.

`-T` *table*
`--exclude-table=`*table*

Do not dump any tables matching the *table* pattern. The pattern is interpreted according to the same rules as for `-t`. `-T` can be given more than once to exclude tables matching any of several patterns.

When both `-t` and `-T` are given, the behavior is to dump just the tables that match at least one `-t` switch but no `-T` switches. If `-T` appears without `-t`, then tables matching `-T` are excluded from what is otherwise a normal dump.

`-v`
`--verbose`

Specifies verbose mode. This will cause pg_dump to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

`-V`
`--version`

Print the pg_dump version and exit.

`-x`
`--no-privileges`
`--no-acl`

Prevent dumping of access privileges (grant/revoke commands).

`-Z` *`0..9`*
`--compress=`*`0..9`*

Specify the compression level to use. Zero means no compression. For the custom archive format, this specifies compression of individual table-data segments, and the default is to compress at a moderate level. For plain text output, setting a nonzero compression level causes the entire output file to be compressed, as though it had been fed through gzip; but the default is not to compress. The tar archive format currently does not support compression at all.

`--binary-upgrade`

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

`--column-inserts`
`--attribute-inserts`

Dump data as `INSERT` commands with explicit column names (`INSERT INTO` *`table`* `(`*`column`*`, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. However, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents.

`--disable-dollar-quoting`

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

`--disable-triggers`

This option is relevant only when creating a data-only dump. It instructs pg_dump to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`--exclude-table-data=`*`table`*

Do not dump data for any tables matching the *`table`* pattern. The pattern is interpreted according to the same rules as for `-t`. `--exclude-table-data` can be given more than once to exclude tables matching any of several patterns. This option is useful when you need the definition of a particular table even though you do not need the data in it.

To exclude data for all tables in the database, see `--schema-only`.

`--if-exists`

Use conditional commands (i.e. add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

`--inserts`

Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. However, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safe against column order changes, though even slower.

`--lock-wait-timeout=`*`timeout`*

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead fail if unable to lock a table within the specified *`timeout`*. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. (Allowed values vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions since 7.3. This option is ignored when dumping from a pre-7.3 server.)

`--no-security-labels`

Do not dump security labels.

`--no-synchronized-snapshots`

This option allows running `pg_dump -j` against a pre-9.2 server, see the documentation of the `-j` parameter for more details.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

This option is only meaningful for the plain-text format. For the archive formats, you can specify the option when you call `pg_restore`.

`--no-unlogged-table-data`

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data. Data in unlogged tables is always excluded when dumping from a standby server.

`--quote-all-identifiers`

Force quoting of all identifiers. This may be useful when dumping a database for migration to a future version that may have introduced additional keywords.

`--section=`*`sectionname`*

Only dump the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to dump all sections.

The data section contains actual table data, large-object contents, and sequence values. Post-data items include definitions of indexes, triggers, rules, and constraints other than validated check constraints. Pre-data items include all other data definition items.

`--serializable-deferrable`

Use a `serializable` transaction for the dump, to ensure that the snapshot used is consistent with later database states; but do this by waiting for a point in the transaction stream at which no anomalies can be present, so that there isn't a risk of the dump failing or causing other transactions to roll back with a `serialization_failure`. See Chapter 13 for more information about transaction isolation and concurrency control.

This option is not beneficial for a dump which is intended only for disaster recovery. It could be useful for a dump used to load a copy of the database for reporting or other read-only load sharing while the original database continues to be updated. Without it the dump may reflect a state which is not consistent with any serial execution of the transactions eventually committed. For example, if batch processing techniques are used, a batch may show as closed in the dump without all of the items which are in the batch appearing.

This option will make no difference if there are no read-write transactions active when pg_dump is started. If read-write transactions are active, the start of the dump may be delayed for an indeterminate length of time. Once running, performance with or without the switch is the same.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly. Also, a dump using `SET SESSION AUTHORIZATION` will certainly require superuser privileges to restore correctly, whereas `ALTER OWNER` requires lesser privileges.

`-?`
`--help`

Show help about pg_dump command line arguments, and exit.

The following command-line options control the database connection parameters.

`-d` *dbname*
`--dbname=`*dbname*

Specifies the name of the database to connect to. This is equivalent to specifying *dbname* as the first non-option argument on the command line.

If this parameter contains an = sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a `conninfo` string. See Section 31.1 for more information.

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_dump to prompt for a password before connecting to a database.

This option is never essential, since pg_dump will automatically prompt for a password if the server demands password authentication. However, pg_dump will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=`*rolename*

Specifies a role name to be used to create the dump. This option causes pg_dump to issue a `SET ROLE` *rolename* command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by pg_dump, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

`PGDATABASE`
`PGHOST`
`PGOPTIONS`
`PGPORT`
`PGUSER`

Default connection parameters.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

pg_dump internally executes `SELECT` statements. If you have problems running pg_dump, make sure you are able to select information from the database using, for example, psql. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

The database activity of pg_dump is normally collected by the statistics collector. If this is undesirable, you can set parameter `track_counts` to false via `PGOPTIONS` or the `ALTER USER` command.

Notes

If your database cluster has any local additions to the `template1` database, be careful to restore the output of pg_dump into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When a data-only dump is chosen and the option `--disable-triggers` is used, pg_dump emits commands to disable triggers on user tables before inserting the data, and then commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.

Members of tar archives are limited to a size less than 8 GB. (This is an inherent limitation of the tar file format.) Therefore this format cannot be used if the textual representation of any one table exceeds that size. The total size of a tar archive and any of the other output formats is not limited, except possibly by the operating system.

The dump file produced by pg_dump does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run `ANALYZE` after restoring from a dump file to ensure optimal performance; see Section 23.1.3 and Section 23.1.6 for more information. The dump file also does not contain any `ALTER DATABASE ... SET` commands; these settings are dumped by pg_dumpall, along with database users and other installation-wide settings.

Because pg_dump is used to transfer data to newer versions of PostgreSQL, the output of pg_dump can be expected to load into PostgreSQL server versions newer than pg_dump's version. pg_dump can also dump from PostgreSQL servers older than its own version. (Currently, servers back to version 7.0 are supported.) However, pg_dump cannot dump from PostgreSQL servers newer than its own major version; it will refuse to even try, rather than risk making an invalid dump. Also, it is not guaranteed that pg_dump's output can be loaded into a server of an older major version — not even if the dump was taken from a server of that version. Loading a dump file into an older server may require manual editing of the dump file to remove syntax not understood by the older server.

Examples

To dump a database called `mydb` into a SQL-script file:

```
$ pg_dump mydb > db.sql
```

To reload such a script into a (freshly created) database named `newdb`:

```
$ psql -d newdb -f db.sql
```

To dump a database into a custom-format archive file:

```
$ pg_dump -Fc mydb > db.dump
```

To dump a database into a directory-format archive:

```
$ pg_dump -Fd mydb -f dumpdir
```

To dump a database into a directory-format archive in parallel with 5 worker jobs:

```
$ pg_dump -Fd mydb -j 5 -f dumpdir
```

To reload an archive file into a (freshly created) database named `newdb`:

```
$ pg_restore -d newdb db.dump
```

To dump a single table named `mytab`:

```
$ pg_dump -t mytab mydb > db.sql
```

To dump all tables whose names start with `emp` in the `detroit` schema, except for the table named `employee_log`:

```
$ pg_dump -t 'detroit.emp*' -T detroit.employee_log mydb > db.sql
```

To dump all schemas whose names start with `east` or `west` and end in `gsm`, excluding any schemas whose names contain the word `test`:

```
$ pg_dump -n 'east*gsm' -n 'west*gsm' -N '*test*' mydb > db.sql
```

The same, using regular expression notation to consolidate the switches:

```
$ pg_dump -n '(east|west)*gsm' -N '*test*' mydb > db.sql
```

To dump all database objects except for tables whose names begin with `ts_`:

```
$ pg_dump -T 'ts_*' mydb > db.sql
```

To specify an upper-case or mixed-case name in `-t` and related switches, you need to double-quote the name; else it will be folded to lower case (see *Patterns*). But double quotes are special to the shell, so in turn they must be quoted. Thus, to dump a single table with a mixed-case name, you need something like

```
$ pg_dump -t "\"MixedCaseName\"" mydb > mytab.sql
```

See Also

pg_dumpall, pg_restore, psql

pg_dumpall

Name

pg_dumpall — extract a PostgreSQL database cluster into a script file

Synopsis

pg_dumpall [*connection-option*...] [*option*...]

Description

pg_dumpall is a utility for writing out ("dumping") all PostgreSQL databases of a cluster into one script file. The script file contains SQL commands that can be used as input to psql to restore the databases. It does this by calling pg_dump for each database in a cluster. pg_dumpall also dumps global objects that are common to all databases. (pg_dump does not save these objects.) This currently includes information about database users and groups, tablespaces, and properties such as access permissions that apply to databases as a whole.

Since pg_dumpall reads tables from all databases you will most likely have to connect as a database superuser in order to produce a complete dump. Also you will need superuser privileges to execute the saved script in order to be allowed to add users and groups, and to create databases.

The SQL script will be written to the standard output. Use the [-flfile] option or shell operators to redirect it into a file.

pg_dumpall needs to connect several times to the PostgreSQL server (once per database). If you use password authentication it will ask for a password each time. It is convenient to have a ~/.pgpass file in such cases. See Section 31.15 for more information.

Options

The following command-line options control the content and format of the output.

-a
--data-only

Dump only the data, not the schema (data definitions).

-c
--clean

Include SQL commands to clean (drop) databases before recreating them. DROP commands for roles and tablespaces are added as well.

-f *filename*
--file=*filename*

Send output to the specified file. If this is omitted, the standard output is used.

`-g`
`--globals-only`

Dump only global objects (roles and tablespaces), no databases.

`-i`
`--ignore-version`

A deprecated option that is now ignored.

`-o`
`--oids`

Dump object identifiers (OIDs) as part of the data for every table. Use this option if your application references the OID columns in some way (e.g., in a foreign key constraint). Otherwise, this option should not be used.

`-O`
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, pg_dumpall issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`.

`-r`
`--roles-only`

Dump only roles, no databases or tablespaces.

`-s`
`--schema-only`

Dump only the object definitions (schema), not data.

`-S` *username*
`--superuser=`*username*

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used. (Usually, it's better to leave this out, and instead start the resulting script as superuser.)

`-t`
`--tablespaces-only`

Dump only tablespaces, no databases or roles.

`-v`
`--verbose`

Specifies verbose mode. This will cause pg_dumpall to output start/stop times to the dump file, and progress messages to standard error. It will also enable verbose output in pg_dump.

`-V`
`--version`

Print the pg_dumpall version and exit.

`-x`
`--no-privileges`
`--no-acl`

Prevent dumping of access privileges (grant/revoke commands).

`--binary-upgrade`

This option is for use by in-place upgrade utilities. Its use for other purposes is not recommended or supported. The behavior of the option may change in future releases without notice.

`--column-inserts`
`--attribute-inserts`

Dump data as `INSERT` commands with explicit column names (`INSERT INTO` *`table`* `(`*`column`*`, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases.

`--disable-dollar-quoting`

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

`--disable-triggers`

This option is relevant only when creating a data-only dump. It instructs pg_dumpall to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So, you should also specify a superuser name with `-S`, or preferably be careful to start the resulting script as a superuser.

`--if-exists`

Use conditional commands (i.e. add an `IF EXISTS` clause) to clean databases and other objects. This option is not valid unless `--clean` is also specified.

`--inserts`

Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL databases. Note that the restore might fail altogether if you have rearranged column order. The `--column-inserts` option is safer, though even slower.

`--lock-wait-timeout=`*`timeout`*

Do not wait forever to acquire shared table locks at the beginning of the dump. Instead, fail if unable to lock a table within the specified *`timeout`*. The timeout may be specified in any of the formats accepted by `SET statement_timeout`. Allowed values vary depending on the server version you are dumping from, but an integer number of milliseconds is accepted by all versions since 7.3. This option is ignored when dumping from a pre-7.3 server.

`--no-security-labels`

Do not dump security labels.

`--no-tablespaces`

Do not output commands to create tablespaces nor select tablespaces for objects. With this option, all objects will be created in whichever tablespace is the default during restore.

`--no-unlogged-table-data`

Do not dump the contents of unlogged tables. This option has no effect on whether or not the table definitions (schema) are dumped; it only suppresses dumping the table data.

`--quote-all-identifiers`

Force quoting of all identifiers. This may be useful when dumping a database for migration to a future version that may have introduced additional keywords.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, might not restore properly.

`-?`
`--help`

Show help about pg_dumpall command line arguments, and exit.

The following command-line options control the database connection parameters.

`-d` *`connstr`*
`--dbname=`*`connstr`*

Specifies parameters used to connect to the server, as a connection string. See Section 31.1.1 for more information.

The option is called `--dbname` for consistency with other client applications, but because pg_dumpall needs to connect to many databases, database name in the connection string will be ignored. Use `-l` option to specify the name of the database used to dump global objects and to discover what other databases should be dumped.

`-h` *`host`*
`--host=`*`host`*

Specifies the host name of the machine on which the database server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-l` *`dbname`*
`--database=`*`dbname`*

Specifies the name of the database to connect to to dump global objects and discover what other databases should be dumped. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

`-p` *`port`*
`--port=`*`port`*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U` *`username`*
`--username=`*`username`*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_dumpall to prompt for a password before connecting to a database.

This option is never essential, since pg_dumpall will automatically prompt for a password if the server demands password authentication. However, pg_dumpall will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Note that the password prompt will occur again for each database to be dumped. Usually, it's better to set up a `~/.pgpass` file than to rely on manual password entry.

`--role=`*`rolename`*

Specifies a role name to be used to create the dump. This option causes pg_dumpall to issue a `SET ROLE` *`rolename`* command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by pg_dumpall, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows dumps to be made without violating the policy.

Environment

`PGHOST`
`PGOPTIONS`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Notes

Since pg_dumpall calls pg_dump internally, some diagnostic messages will refer to pg_dump.

Once restored, it is wise to run `ANALYZE` on each database so the optimizer has useful statistics. You can also run `vacuumdb -a -z` to analyze all databases.

pg_dumpall requires all needed tablespace directories to exist before the restore; otherwise, database creation will fail for databases in non-default locations.

Examples

To dump all databases:

```
$ pg_dumpall > db.out
```

To reload database(s) from this file, you can use:

```
$ psql -f db.out postgres
```

(It is not important to which database you connect here since the script file created by pg_dumpall will contain the appropriate commands to create and connect to the saved databases.)

See Also

Check pg_dump for details on possible error conditions.

pg_isready

Name

pg_isready — check the connection status of a PostgreSQL server

Synopsis

pg_isready [*connection-option*...] [*option*...]

Description

pg_isready is a utility for checking the connection status of a PostgreSQL database server. The exit status specifies the result of the connection check.

Options

-d *dbname*
--dbname=*dbname*

Specifies the name of the database to connect to.

If this parameter contains an = sign or starts with a valid URI prefix (postgresql:// or postgres://), it is treated as a conninfo string. See Section 31.1.1 for more information.

-h *hostname*
--host=*hostname*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

-p *port*
--port=*port*

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the PGPORT environment variable or, if not set, to the port specified at compile time, usually 5432.

-q
--quiet

Do not display status message. This is useful when scripting.

-t *seconds*
--timeout=*seconds*

The maximum number of seconds to wait when attempting connection before returning that the server is not responding. Setting to 0 disables. The default is 3 seconds.

-U *username*
--username=*username*

Connect to the database as the user *username* instead of the default.

`-V`
`--version`

Print the pg_isready version and exit.

`-?`
`--help`

Show help about pg_isready command line arguments, and exit.

Exit Status

pg_isready returns `0` to the shell if the server is accepting connections normally, `1` if the server is rejecting connections (for example during startup), `2` if there was no response to the connection attempt, and `3` if no attempt was made (for example due to invalid parameters).

Environment

`pg_isready`, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Notes

It is not necessary to supply correct user name, password, or database name values to obtain the server status; however, if incorrect values are provided, the server will log a failed connection attempt.

Examples

Standard Usage:

```
$ pg_isready
/tmp:5432 - accepting connections
$ echo $?
0
```

Running with connection parameters to a PostgreSQL cluster in startup:

```
$ pg_isready -h localhost -p 5433
localhost:5433 - rejecting connections
$ echo $?
1
```

Running with connection parameters to a non-responsive PostgreSQL cluster:

```
$ pg_isready -h someremotehost
someremotehost:5432 - no response
$ echo $?
2
```

pg_receivexlog

Name

pg_receivexlog — stream transaction logs from a PostgreSQL server

Synopsis

pg_receivexlog [*option*...]

Description

pg_receivexlog is used to stream transaction log from a running PostgreSQL cluster. The transaction log is streamed using the streaming replication protocol, and is written to a local directory of files. This directory can be used as the archive location for doing a restore using point-in-time recovery (see Section 24.3).

pg_receivexlog streams the transaction log in real time as it's being generated on the server, and does not wait for segments to complete like archive_command does. For this reason, it is not necessary to set archive_timeout when using pg_receivexlog.

The transaction log is streamed over a regular PostgreSQL connection, and uses the replication protocol. The connection must be made with a superuser or a user having REPLICATION permissions (see Section 20.2), and pg_hba.conf must explicitly permit the replication connection. The server must also be configured with max_wal_senders set high enough to leave at least one session available for the stream.

If the connection is lost, or if it cannot be initially established, with a non-fatal error, pg_receivexlog will retry the connection indefinitely, and reestablish streaming as soon as possible. To avoid this behavior, use the -n parameter.

Options

-D *directory*
--directory=*directory*

Directory to write the output to.

This parameter is required.

-n
--no-loop

Don't loop on connection errors. Instead, exit right away with an error.

-s *interval*
--status-interval=*interval*

Specifies the number of seconds between status packets sent back to the server. This allows for easier monitoring of the progress from server. A value of zero disables the periodic status updates completely, although an update will still be sent when requested by the server, to avoid timeout disconnect. The default value is 10 seconds.

`-S` *slotname*
`--slot=`*slotname*

Require pg_receivexlog to use an existing replication slot (see Section 25.2.6). When this option is used, pg_receivexlog will report a flush position to the server, indicating when each segment has been synchronized to disk so that the server can remove that segment if it is not otherwise needed. When using this parameter, it is important to make sure that pg_receivexlog cannot become the synchronous standby through an incautious setting of synchronous_standby_names; it does not flush data frequently enough for this to work correctly.

`-v`
`--verbose`

Enables verbose mode.

The following command-line options control the database connection parameters.

`-d` *connstr*
`--dbname=`*connstr*

Specifies parameters used to connect to the server, as a connection string. See Section 31.1.1 for more information.

The option is called `--dbname` for consistency with other client applications, but because pg_receivexlog doesn't connect to any particular database in the cluster, database name in the connection string will be ignored.

`-h` *host*
`--host=`*host*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_receivexlog to prompt for a password before connecting to a database.

This option is never essential, since pg_receivexlog will automatically prompt for a password if the server demands password authentication. However, pg_receivexlog will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Other options are also available:

`-V`
`--version`

Print the pg_receivexlog version and exit.

`-?`
`--help`

Show help about pg_receivexlog command line arguments, and exit.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by libpq (see Section 31.14).

Notes

When using pg_receivexlog instead of archive_command as the main WAL backup method, it is strongly recommended to use replication slots. Otherwise, the server is free to recycle or remove transaction log files before they are backed up, because it does not have any information, either from archive_command or the replication slots, about how far the WAL stream has been archived. Note, however, that a replication slot will fill up the server's disk space if the receiver does not keep up with fetching the WAL data.

Examples

To stream the transaction log from the server at `mydbserver` and store it in the local directory `/usr/local/pgsql/archive`:

```
$ pg_receivexlog -h mydbserver -D /usr/local/pgsql/archive
```

See Also

pg_basebackup

pg_recvlogical

Name

pg_recvlogical — control PostgreSQL logical decoding streams

Synopsis

pg_recvlogical [*option*...]

Description

pg_recvlogical controls logical decoding replication slots and streams data from such replication slots.

It creates a replication-mode connection, so it is subject to the same constraints as pg_receivexlog, plus those for logical replication (see Chapter 46).

Options

At least one of the following options must be specified to select an action:

--create-slot

Create a new logical replication slot with the name specified by --slot, using the output plugin specified by --plugin, for the database specified by --dbname.

--drop-slot

Drop the replication slot with the name specified by --slot, then exit.

--start

Begin streaming changes from the logical replication slot specified by --slot, continuing until terminated by a signal. If the server side change stream ends with a server shutdown or disconnect, retry in a loop unless --no-loop is specified.

The stream format is determined by the output plugin specified when the slot was created.

The connection must be to the same database used to create the slot.

--create-slot and --start can be specified together. --drop-slot cannot be combined with another action.

The following command-line options control the location and format of the output and other replication behavior:

-f *filename*
--file=*filename*

Write received and decoded transaction data into this file. Use - for stdout.

`-F` *interval_seconds*
`--fsync-interval=`*interval_seconds*

Specifies how often pg_recvlogical should issue `fsync()` calls to ensure the output file is safely flushed to disk.

The server will occasionally request the client to perform a flush and report the flush position to the server. This setting is in addition to that, to perform flushes more frequently.

Specifying an interval of `0` disables issuing `fsync()` calls altogether, while still reporting progress to the server. In this case, data could be lost in the event of a crash.

`-I` *lsn*
`--startpos=`*lsn*

In `--start` mode, start replication from the given LSN. For details on the effect of this, see the documentation in Chapter 46 and Section 49.3. Ignored in other modes.

`-n`
`--no-loop`

When the connection to the server is lost, do not retry in a loop, just exit.

`-o` *name*`[=`*value*`]`
`--option=`*name*`[=`*value*`]`

Pass the option *name* to the output plugin with, if specified, the option value *value*. Which options exist and their effects depends on the used output plugin.

`-P` *plugin*
`--plugin=`*plugin*

When creating a slot, use the specified logical decoding output plugin. See Chapter 46. This option has no effect if the slot already exists.

`-s` *interval_seconds*
`--status-interval=`*interval_seconds*

This option has the same effect as the option of the same name in pg_receivexlog. See the description there.

`-S` *slot_name*
`--slot=`*slot_name*

In `--start` mode, use the existing logical replication slot named *slot_name*. In `--create-slot` mode, create the slot with this name. In `--drop-slot` mode, delete the slot with this name.

`-v`
`--verbose`

Enables verbose mode.

The following command-line options control the database connection parameters.

`-d` *database*
`--dbname=`*database*

The database to connect to. See the description of the actions for what this means in detail. This can be a libpq connection string; see Section 31.1.1 for more information. Defaults to user name.

`-h` *hostname-or-ip*
`--host=`*hostname-or-ip*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U` *user*
`--username=`*user*

Username to connect as. Defaults to current operating system user name.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_recvlogical to prompt for a password before connecting to a database.

This option is never essential, since pg_recvlogical will automatically prompt for a password if the server demands password authentication. However, pg_recvlogical will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

The following additional options are available:

`-V`
`--version`

Print the pg_recvlogical version and exit.

`-?`
`--help`

Show help about pg_recvlogical command line arguments, and exit.

Environment

This utility, like most other PostgreSQL utilities, uses the environment variables supported by libpq (see Section 31.14).

Examples

See Section 46.1 for an example.

See Also

pg_receivexlog

pg_restore

Name

pg_restore — restore a PostgreSQL database from an archive file created by pg_dump

Synopsis

pg_restore [*connection-option*...] [*option*...] [*filename*]

Description

pg_restore is a utility for restoring a PostgreSQL database from an archive created by pg_dump in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow pg_restore to be selective about what is restored, or even to reorder the items prior to being restored. The archive files are designed to be portable across architectures.

pg_restore can operate in two modes. If a database name is specified, pg_restore connects to that database and restores archive contents directly into the database. Otherwise, a script containing the SQL commands necessary to rebuild the database is created and written to a file or standard output. This script output is equivalent to the plain text output format of pg_dump. Some of the options controlling the output are therefore analogous to pg_dump options.

Obviously, pg_restore cannot restore information that is not present in the archive file. For instance, if the archive was made using the "dump data as INSERT commands" option, pg_restore will not be able to load the data using COPY statements.

Options

pg_restore accepts the following command line arguments.

filename

Specifies the location of the archive file (or directory, for a directory-format archive) to be restored. If not specified, the standard input is used.

-a
--data-only

Restore only the data, not the schema (data definitions). Table data, large objects, and sequence values are restored, if present in the archive.

This option is similar to, but for historical reasons not identical to, specifying --section=data.

-c
--clean

Clean (drop) database objects before recreating them. (Unless --if-exists is used, this might generate some harmless error messages, if any objects were not present in the destination database.)

`-C`
`--create`

Create the database before restoring into it. If `--clean` is also specified, drop and recreate the target database before connecting to it.

When this option is used, the database named with `-d` is used only to issue the initial `DROP DATABASE` and `CREATE DATABASE` commands. All data is restored into the database name that appears in the archive.

`-d` *dbname*
`--dbname=`*dbname*

Connect to database *dbname* and restore directly into the database.

`-e`
`--exit-on-error`

Exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

`-f` *filename*
`--file=`*filename*

Specify output file for generated script, or for the listing when used with `-l`. Default is the standard output.

`-F` *format*
`--format=`*format*

Specify format of the archive. It is not necessary to specify the format, since pg_restore will determine the format automatically. If specified, it can be one of the following:

`c`
`custom`

The archive is in the custom format of pg_dump.

`d`
`directory`

The archive is a directory archive.

`t`
`tar`

The archive is a `tar` archive.

`-i`
`--ignore-version`

A deprecated option that is now ignored.

`-I` *index*
`--index=`*index*

Restore definition of named index only. Multiple indexes may be specified with multiple `-I` switches.

`-j` *number-of-jobs*
`--jobs=`*number-of-jobs*

Run the most time-consuming parts of pg_restore — those which load data, create indexes, or create constraints — using multiple concurrent jobs. This option can dramatically reduce the time to restore a large database to a server running on a multiprocessor machine.

Each job is one process or one thread, depending on the operating system, and uses a separate connection to the server.

The optimal value for this option depends on the hardware setup of the server, of the client, and of the network. Factors include the number of CPU cores and the disk setup. A good place to start is the number of CPU cores on the server, but values larger than that can also lead to faster restore times in many cases. Of course, values that are too high will lead to decreased performance because of thrashing.

Only the custom and directory archive formats are supported with this option. The input must be a regular file or directory (not, for example, a pipe). This option is ignored when emitting a script rather than connecting directly to a database server. Also, multiple jobs cannot be used together with the option `--single-transaction`.

`-l`
`--list`

List the contents of the archive. The output of this operation can be used as input to the `-L` option. Note that if filtering switches such as `-n` or `-t` are used with `-l`, they will restrict the items listed.

`-L` *list-file*
`--use-list=`*list-file*

Restore only those archive elements that are listed in *list-file*, and restore them in the order they appear in the file. Note that if filtering switches such as `-n` or `-t` are used with `-L`, they will further restrict the items restored.

list-file is normally created by editing the output of a previous `-l` operation. Lines can be moved or removed, and can also be commented out by placing a semicolon (`;`) at the start of the line. See below for examples.

`-n` *namespace*
`--schema=`*schema*

Restore only objects that are in the named schema. Multiple schemas may be specified with multiple `-n` switches. This can be combined with the `-t` option to restore just a specific table.

`-O`
`--no-owner`

Do not output commands to set ownership of objects to match the original database. By default, pg_restore issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With `-O`, any user name can be used for the initial connection, and this user will own all the created objects.

`-P` *function-name(argtype [, ...])*
`--function=`*function-name(argtype [, ...])*

Restore the named function only. Be careful to spell the function name and arguments exactly as they appear in the dump file's table of contents. Multiple functions may be specified with multiple `-P` switches.

`-R`
`--no-reconnect`

This option is obsolete but still accepted for backwards compatibility.

`-s`
`--schema-only`

Restore only the schema (data definitions), not data, to the extent that schema entries are present in the archive.

This option is the inverse of `--data-only`. It is similar to, but for historical reasons not identical to, specifying `--section=pre-data --section=post-data`.

(Do not confuse this with the `--schema` option, which uses the word "schema" in a different meaning.)

`-S` *username*
`--superuser=`*username*

Specify the superuser user name to use when disabling triggers. This is relevant only if `--disable-triggers` is used.

`-t` *table*
`--table=`*table*

Restore definition and/or data of named table only. Multiple tables may be specified with multiple `-t` switches. This can be combined with the `-n` option to specify a schema.

`-T` *trigger*
`--trigger=`*trigger*

Restore named trigger only. Multiple triggers may be specified with multiple `-T` switches.

`-v`
`--verbose`

Specifies verbose mode.

`-V`
`--version`

Print the pg_restore version and exit.

`-x`
`--no-privileges`
`--no-acl`

Prevent restoration of access privileges (grant/revoke commands).

`-1`
`--single-transaction`

Execute the restore as a single transaction (that is, wrap the emitted commands in `BEGIN`/`COMMIT`). This ensures that either all the commands complete successfully, or no changes are applied. This option implies `--exit-on-error`.

`--disable-triggers`

This option is relevant only when performing a data-only restore. It instructs pg_restore to execute commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have referential integrity checks or other triggers on the tables that you do not want to invoke during data reload.

Presently, the commands emitted for `--disable-triggers` must be done as superuser. So you should also specify a superuser name with `-S` or, preferably, run pg_restore as a PostgreSQL superuser.

`--if-exists`

Use conditional commands (i.e. add an `IF EXISTS` clause) when cleaning database objects. This option is not valid unless `--clean` is also specified.

`--no-data-for-failed-tables`

By default, table data is restored even if the creation command for the table failed (e.g., because it already exists). With this option, data for such a table is skipped. This behavior is useful if the target database already contains the desired table contents. For example, auxiliary tables for PostgreSQL extensions such as PostGIS might already be loaded in the target database; specifying this option prevents duplicate or obsolete data from being loaded into them.

This option is effective only when restoring directly into a database, not when producing SQL script output.

`--no-security-labels`

Do not output commands to restore security labels, even if the archive contains them.

`--no-tablespaces`

Do not output commands to select tablespaces. With this option, all objects will be created in whichever tablespace is the default during restore.

`--section=`*`sectionname`*

Only restore the named section. The section name can be `pre-data`, `data`, or `post-data`. This option can be specified more than once to select multiple sections. The default is to restore all sections.

The data section contains actual table data as well as large-object definitions. Post-data items consist of definitions of indexes, triggers, rules and constraints other than validated check constraints. Pre-data items consist of all other data definition items.

`--use-set-session-authorization`

Output SQL-standard `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to determine object ownership. This makes the dump more standards-compatible, but depending on the history of the objects in the dump, might not restore properly.

`-?`
`--help`

Show help about pg_restore command line arguments, and exit.

pg_restore also accepts the following command line arguments for connection parameters:

`-h` *`host`*
`--host=`*`host`*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket. The default is taken from the `PGHOST` environment variable, if set, else a Unix domain socket connection is attempted.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections. Defaults to the `PGPORT` environment variable, if set, or a compiled-in default.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force pg_restore to prompt for a password before connecting to a database.

This option is never essential, since pg_restore will automatically prompt for a password if the server demands password authentication. However, pg_restore will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--role=`*rolename*

Specifies a role name to be used to perform the restore. This option causes pg_restore to issue a `SET ROLE` *rolename* command after connecting to the database. It is useful when the authenticated user (specified by `-U`) lacks privileges needed by pg_restore, but can switch to a role with the required rights. Some installations have a policy against logging in directly as a superuser, and use of this option allows restores to be performed without violating the policy.

Environment

`PGHOST`
`PGOPTIONS`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14). However, it does not read `PGDATABASE` when a database name is not supplied.

Diagnostics

When a direct database connection is specified using the `-d` option, pg_restore internally executes SQL statements. If you have problems running pg_restore, make sure you are able to select information from the database using, for example, psql. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

If your installation has any local additions to the `template1` database, be careful to load the output of pg_restore into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from `template0` not `template1`, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

The limitations of pg_restore are detailed below.

- When restoring data to a pre-existing table and the option `--disable-triggers` is used, pg_restore emits commands to disable triggers on user tables before inserting the data, then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs might be left in the wrong state.
- pg_restore cannot restore large objects selectively; for instance, only those for a specific table. If an archive contains large objects, then all large objects will be restored, or none of them if they are excluded via `-L`, `-t`, or other options.

See also the pg_dump documentation for details on limitations of pg_dump.

Once restored, it is wise to run `ANALYZE` on each restored table so the optimizer has useful statistics; see Section 23.1.3 and Section 23.1.6 for more information.

Examples

Assume we have dumped a database called `mydb` into a custom-format dump file:

```
$ pg_dump -Fc mydb > db.dump
```

To drop the database and recreate it from the dump:

```
$ dropdb mydb
$ pg_restore -C -d postgres db.dump
```

The database named in the `-d` switch can be any database existing in the cluster; pg_restore only uses it to issue the `CREATE DATABASE` command for `mydb`. With `-C`, data is always restored into the database name that appears in the dump file.

To reload the dump into a new database called `newdb`:

```
$ createdb -T template0 newdb
$ pg_restore -d newdb db.dump
```

Notice we don't use `-C`, and instead connect directly to the database to be restored into. Also note that we clone the new database from `template0` not `template1`, to ensure it is initially empty.

To reorder database items, it is first necessary to dump the table of contents of the archive:

```
$ pg_restore -l db.dump > db.list
```

The listing file consists of a header and one line for each item, e.g.:

```
;
; Archive created at Mon Sep 14 13:55:39 2009
;     dbname: DBDEMOS
;     TOC Entries: 81
;     Compression: 9
;     Dump Version: 1.10-0
;     Format: CUSTOM
;     Integer: 4 bytes
;     Offset: 8 bytes
;     Dumped from database version: 8.3.5
;     Dumped by pg_dump version: 8.3.8
;
;
; Selected TOC Entries:
;
3; 2615 2200 SCHEMA - public pasha
1861; 0 0 COMMENT - SCHEMA public pasha
1862; 0 0 ACL - public pasha
317; 1247 17715 TYPE public composite pasha
319; 1247 25899 DOMAIN public domain0 pasha
```

Semicolons start a comment, and the numbers at the start of lines refer to the internal archive ID assigned to each item.

Lines in the file can be commented out, deleted, and reordered. For example:

```
10; 145433 TABLE map_resolutions postgres
;2; 145344 TABLE species postgres
;4; 145359 TABLE nt_header postgres
6; 145402 TABLE species_records postgres
;8; 145416 TABLE ss_old postgres
```

could be used as input to pg_restore and would only restore items 10 and 6, in that order:

```
$ pg_restore -L db.list db.dump
```

See Also

pg_dump, pg_dumpall, psql

psql

Name

psql — PostgreSQL interactive terminal

Synopsis

psql [*option*...] [*dbname* [*username*]]

Description

psql is a terminal-based front-end to PostgreSQL. It enables you to type in queries interactively, issue them to PostgreSQL, and see the query results. Alternatively, input can be from a file. In addition, it provides a number of meta-commands and various shell-like features to facilitate writing scripts and automating a wide variety of tasks.

Options

-a
--echo-all

Print all nonempty input lines to standard output as they are read. (This does not apply to lines read interactively.) This is equivalent to setting the variable ECHO to all.

-A
--no-align

Switches to unaligned output mode. (The default output mode is otherwise aligned.)

-c *command*
--command=*command*

Specifies that psql is to execute one command string, *command*, and then exit. This is useful in shell scripts. Start-up files (psqlrc and ~/.psqlrc) are ignored with this option.

command must be either a command string that is completely parsable by the server (i.e., it contains no psql-specific features), or a single backslash command. Thus you cannot mix SQL and psql meta-commands with this option. To achieve that, you could pipe the string into psql, for example: `echo '\x \\ SELECT * FROM foo;' | psql`. (\\ is the separator meta-command.)

If the command string contains multiple SQL commands, they are processed in a single transaction, unless there are explicit BEGIN/COMMIT commands included in the string to divide it into multiple transactions. This is different from the behavior when the same string is fed to psql's standard input. Also, only the result of the last SQL command is returned.

Because of these legacy behaviors, putting more than one command in the -c string often has unexpected results. It's better to feed multiple commands to psql's standard input, either using echo as illustrated above, or via a shell here-document, for example:

```
psql <<EOF
```

```
\x
SELECT * FROM foo;
EOF
```

`-d` *dbname*
`--dbname=`*dbname*

Specifies the name of the database to connect to. This is equivalent to specifying *dbname* as the first non-option argument on the command line.

If this parameter contains an `=` sign or starts with a valid URI prefix (`postgresql://` or `postgres://`), it is treated as a `conninfo` string. See Section 31.1.1 for more information.

`-e`
`--echo-queries`

Copy all SQL commands sent to the server to standard output as well. This is equivalent to setting the variable `ECHO` to `queries`.

`-E`
`--echo-hidden`

Echo the actual queries generated by `\d` and other backslash commands. You can use this to study psql's internal operations. This is equivalent to setting the variable `ECHO_HIDDEN` to `on`.

`-f` *filename*
`--file=`*filename*

Use the file *filename* as the source of commands instead of reading commands interactively. After the file is processed, psql terminates. This is in many ways equivalent to the meta-command `\i`.

If *filename* is `-` (hyphen), then standard input is read.

Using this option is subtly different from writing `psql < `*filename*. In general, both will do what you expect, but using `-f` enables some nice features such as error messages with line numbers. There is also a slight chance that using this option will reduce the start-up overhead. On the other hand, the variant using the shell's input redirection is (in theory) guaranteed to yield exactly the same output you would have received had you entered everything by hand.

`-F` *separator*
`--field-separator=`*separator*

Use *separator* as the field separator for unaligned output. This is equivalent to `\pset fieldsep` or `\f`.

`-h` *hostname*
`--host=`*hostname*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix-domain socket.

`-H`
`--html`

Turn on HTML tabular output. This is equivalent to `\pset format html` or the `\H` command.

`-l`
`--list`

List all available databases, then exit. Other non-connection options are ignored. This is similar to the meta-command `\list`.

`-L` *`filename`*
`--log-file=`*`filename`*

Write all query output into file *`filename`*, in addition to the normal output destination.

`-n`
`--no-readline`

Do not use Readline for line editing and do not use the command history. This can be useful to turn off tab expansion when cutting and pasting.

`-o` *`filename`*
`--output=`*`filename`*

Put all query output into file *`filename`*. This is equivalent to the command `\o`.

`-p` *`port`*
`--port=`*`port`*

Specifies the TCP port or the local Unix-domain socket file extension on which the server is listening for connections. Defaults to the value of the `PGPORT` environment variable or, if not set, to the port specified at compile time, usually 5432.

`-P` *`assignment`*
`--pset=`*`assignment`*

Specifies printing options, in the style of `\pset`. Note that here you have to separate name and value with an equal sign instead of a space. For example, to set the output format to LaTeX, you could write `-P format=latex`.

`-q`
`--quiet`

Specifies that psql should do its work quietly. By default, it prints welcome messages and various informational output. If this option is used, none of this happens. This is useful with the `-c` option. This is equivalent to setting the variable `QUIET` to `on`.

`-R` *`separator`*
`--record-separator=`*`separator`*

Use *`separator`* as the record separator for unaligned output. This is equivalent to the `\pset recordsep` command.

`-s`
`--single-step`

Run in single-step mode. That means the user is prompted before each command is sent to the server, with the option to cancel execution as well. Use this to debug scripts.

`-S`
`--single-line`

Runs in single-line mode where a newline terminates an SQL command, as a semicolon does.

> **Note:** This mode is provided for those who insist on it, but you are not necessarily encouraged to use it. In particular, if you mix SQL and meta-commands on a line the order of execution might not always be clear to the inexperienced user.

`-t`
`--tuples-only`

Turn off printing of column names and result row count footers, etc. This is equivalent to the `\t` command.

`-T` *`table_options`*
`--table-attr=`*`table_options`*

Specifies options to be placed within the HTML `table` tag. See `\pset` for details.

`-U` *`username`*
`--username=`*`username`*

Connect to the database as the user *`username`* instead of the default. (You must have permission to do so, of course.)

`-v` *`assignment`*
`--set=`*`assignment`*
`--variable=`*`assignment`*

Perform a variable assignment, like the `\set` meta-command. Note that you must separate name and value, if any, by an equal sign on the command line. To unset a variable, leave off the equal sign. To set a variable with an empty value, use the equal sign but leave off the value. These assignments are done during a very early stage of start-up, so variables reserved for internal purposes might get overwritten later.

`-V`
`--version`

Print the psql version and exit.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-W`
`--password`

Force psql to prompt for a password before connecting to a database.

This option is never essential, since psql will automatically prompt for a password if the server demands password authentication. However, psql will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Note that this option will remain set for the entire session, and so it affects uses of the meta-command `\connect` as well as the initial connection attempt.

`-x`
`--expanded`

Turn on the expanded table formatting mode. This is equivalent to the `\x` command.

`-X`,
`--no-psqlrc`

Do not read the start-up file (neither the system-wide `psqlrc` file nor the user's `~/.psqlrc` file).

`-z`
`--field-separator-zero`

Set the field separator for unaligned output to a zero byte.

`-0`
`--record-separator-zero`

Set the record separator for unaligned output to a zero byte. This is useful for interfacing, for example, with `xargs -0`.

`-1`
`--single-transaction`

When psql executes a script, adding this option wraps `BEGIN`/`COMMIT` around the script to execute it as a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.

If the script itself uses `BEGIN`, `COMMIT`, or `ROLLBACK`, this option will not have the desired effects. Also, if the script contains any command that cannot be executed inside a transaction block, specifying this option will cause that command (and hence the whole transaction) to fail.

`-?`
`--help`

Show help about psql command line arguments, and exit.

Exit Status

psql returns 0 to the shell if it finished normally, 1 if a fatal error of its own occurs (e.g. out of memory, file not found), 2 if the connection to the server went bad and the session was not interactive, and 3 if an error occurred in a script and the variable `ON_ERROR_STOP` was set.

Usage

Connecting to a Database

psql is a regular PostgreSQL client application. In order to connect to a database you need to know the name of your target database, the host name and port number of the server, and what user name you want to connect as. psql can be told about those parameters via command line options, namely `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option it will be interpreted as the database name (or the user name, if the database name is already given). Not all of these options are required; there are useful defaults. If you omit the host name, psql will connect via a Unix-domain socket to a server on the local host, or via TCP/IP to `localhost` on machines that don't have Unix-domain sockets. The default port number is determined at compile time. Since the database server uses the same default, you will not have to specify the port in most cases. The default user name is your operating-system user name, as is the default database name. Note that you cannot just connect to any database under any user name. Your database administrator should have informed you about your access rights.

When the defaults aren't quite right, you can save yourself some typing by setting the environment variables `PGDATABASE`, `PGHOST`, `PGPORT` and/or `PGUSER` to appropriate values. (For additional environment variables, see Section 31.14.) It is also convenient to have a `~/.pgpass` file to avoid regularly having to type in passwords. See Section 31.15 for more information.

An alternative way to specify connection parameters is in a `conninfo` string or a URI, which is used instead of a database name. This mechanism give you very wide control over the connection. For example:

```
$ psql "service=myservice sslmode=require"
$ psql postgresql://dbmaster:5433/mydb?sslmode=require
```

This way you can also use LDAP for connection parameter lookup as described in Section 31.17. See Section 31.1.2 for more information on all the available connection options.

If the connection could not be made for any reason (e.g., insufficient privileges, server is not running on the targeted host, etc.), psql will return an error and terminate.

If both standard input and standard output are a terminal, then psql sets the client encoding to "auto", which will detect the appropriate client encoding from the locale settings (`LC_CTYPE` environment variable on Unix systems). If this doesn't work out as expected, the client encoding can be overridden using the environment variable `PGCLIENTENCODING`.

Entering SQL Commands

In normal operation, psql provides a prompt with the name of the database to which psql is currently connected, followed by the string =>. For example:

```
$ psql testdb
psql (9.4.1)
Type "help" for help.

testdb=>
```

At the prompt, the user can type in SQL commands. Ordinarily, input lines are sent to the server when a command-terminating semicolon is reached. An end of line does not terminate a command. Thus commands can be spread over several lines for clarity. If the command was sent and executed without error, the results of the command are displayed on the screen.

Whenever a command is executed, psql also polls for asynchronous notification events generated by LISTEN and NOTIFY.

While C-style block comments are passed to the server for processing and removal, SQL-standard comments are removed by psql.

Meta-Commands

Anything you enter in psql that begins with an unquoted backslash is a psql meta-command that is processed by psql itself. These commands make psql more useful for administration or scripting. Meta-commands are often called slash or backslash commands.

The format of a psql command is the backslash, followed immediately by a command verb, then any arguments. The arguments are separated from the command verb and each other by any number of whitespace characters.

To include whitespace in an argument you can quote it with single quotes. To include a single quote in an argument, write two single quotes within single-quoted text. Anything contained in single quotes is furthermore subject to C-like substitutions for `\n` (new line), `\t` (tab), `\b` (backspace), `\r` (carriage return), `\f` (form feed), `\`*`digits`* (octal), and `\x`*`digits`* (hexadecimal). A backslash preceding any other character within single-quoted text quotes that single character, whatever it is.

Within an argument, text that is enclosed in backquotes (`) is taken as a command line that is passed to the shell. The output of the command (with any trailing newline removed) replaces the backquoted text.

If an unquoted colon (`:`) followed by a psql variable name appears within an argument, it is replaced by the variable's value, as described in *SQL Interpolation*.

Some commands take an SQL identifier (such as a table name) as argument. These arguments follow the syntax rules of SQL: Unquoted letters are forced to lowercase, while double quotes (`"`) protect letters from case conversion and allow incorporation of whitespace into the identifier. Within double quotes, paired double quotes reduce to a single double quote in the resulting name. For example, `FOO"BAR"BAZ` is interpreted as `fooBARbaz`, and `"A weird"" name"` becomes `A weird" name`.

Parsing for arguments stops at the end of the line, or when another unquoted backslash is found. An unquoted backslash is taken as the beginning of a new meta-command. The special sequence `\\` (two backslashes) marks the end of arguments and continues parsing SQL commands, if any. That way SQL and psql commands can be freely mixed on a line. But in any case, the arguments of a meta-command cannot continue beyond the end of the line.

The following meta-commands are defined:

`\a`

If the current table output format is unaligned, it is switched to aligned. If it is not unaligned, it is set to unaligned. This command is kept for backwards compatibility. See `\pset` for a more general solution.

`\c` or `\connect [ `*`dbname`*` [ `*`username`*` ] [ `*`host`*` ] [ `*`port`*` ] ]`

Establishes a new connection to a PostgreSQL server. If the new connection is successfully made, the previous connection is closed. If any of *`dbname`*, *`username`*, *`host`* or *`port`* are omitted or specified as `-`, the value of that parameter from the previous connection is used. If there is no previous connection, the libpq default for the parameter's value is used.

If the connection attempt failed (wrong user name, access denied, etc.), the previous connection will only be kept if psql is in interactive mode. When executing a non-interactive script, processing will immediately stop with an error. This distinction was chosen as a user convenience against typos on the one hand, and a safety mechanism that scripts are not accidentally acting on the wrong database on the other hand.

`\C [ `*`title`*` ]`

Sets the title of any tables being printed as the result of a query or unset any such title. This command is equivalent to `\pset title `*`title`*. (The name of this command derives from "caption", as it was previously only used to set the caption in an HTML table.)

`\cd [ `*`directory`*` ]`

Changes the current working directory to *`directory`*. Without argument, changes to the current user's home directory.

> **Tip:** To print your current working directory, use `\! pwd`.

`\conninfo`

Outputs information about the current database connection.

`\copy { table [ ( column_list ) ] | ( query ) } { from | to } { 'filename' | program 'command' | stdin | stdout | pstdin | pstdout } [ [ with ] ( option [, ...] ) ]`

Performs a frontend (client) copy. This is an operation that runs an SQL COPY command, but instead of the server reading or writing the specified file, psql reads or writes the file and routes the data between the server and the local file system. This means that file accessibility and privileges are those of the local user, not the server, and no SQL superuser privileges are required.

When `program` is specified, *command* is executed by psql and the data passed from or to *command* is routed between the server and the client. Again, the execution privileges are those of the local user, not the server, and no SQL superuser privileges are required.

For `\copy ... from stdin`, data rows are read from the same source that issued the command, continuing until `\.` is read or the stream reaches EOF. This option is useful for populating tables in-line within a SQL script file. For `\copy ... to stdout`, output is sent to the same place as psql command output, and the `COPY` *count* command status is not printed (since it might be confused with a data row). To read/write psql's standard input or output regardless of the current command source or `\o` option, write `from pstdin` or `to pstdout`.

The syntax of this command is similar to that of the SQL COPY command. All options other than the data source/destination are as specified for COPY. Because of this, special parsing rules apply to the `\copy` command. In particular, psql's variable substitution rules and backslash escapes do not apply.

> **Tip:** This operation is not as efficient as the SQL `COPY` command because all data must pass through the client/server connection. For large amounts of data the SQL command might be preferable.

`\copyright`

Shows the copyright and distribution terms of PostgreSQL.

`\d[S+] [ pattern ]`

For each relation (table, view, index, sequence, or foreign table) or composite type matching the *pattern*, show all columns, their types, the tablespace (if not the default) and any special attributes such as `NOT NULL` or defaults. Associated indexes, constraints, rules, and triggers are also shown. For foreign tables, the associated foreign server is shown as well. ("Matching the pattern" is defined in *Patterns* below.)

For some types of relation, `\d` shows additional information for each column: column values for sequences, indexed expression for indexes and foreign data wrapper options for foreign tables.

The command form `\d+` is identical, except that more information is displayed: any comments associated with the columns of the table are shown, as is the presence of OIDs in the table, the view definition if the relation is a view, a non-default replica identity setting.

By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

> **Note:** If `\d` is used without a *pattern* argument, it is equivalent to `\dtvsE` which will show a list of all visible tables, views, sequences and foreign tables. This is purely a convenience measure.

`\da[S] [ pattern ]`

Lists aggregate functions, together with their return type and the data types they operate on. If *pattern* is specified, only aggregates whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

`\db[+] [ pattern ]`

Lists tablespaces. If *pattern* is specified, only tablespaces whose names match the pattern are shown. If + is appended to the command name, each object is listed with its associated permissions.

`\dc[S+] [ pattern ]`

Lists conversions between character-set encodings. If *pattern* is specified, only conversions whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If + is appended to the command name, each object is listed with its associated description.

`\dC[+] [ pattern ]`

Lists type casts. If *pattern* is specified, only casts whose source or target types match the pattern are listed. If + is appended to the command name, each object is listed with its associated description.

`\dd[S] [ pattern ]`

Shows the descriptions of objects of type `constraint`, `operator class`, `operator family`, `rule`, and `trigger`. All other comments may be viewed by the respective backslash commands for those object types.

`\dd` displays descriptions for objects matching the *pattern*, or of visible objects of the appropriate type if no argument is given. But in either case, only objects that have a description are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

Descriptions for objects can be created with the COMMENT SQL command.

`\ddp [ pattern ]`

Lists default access privilege settings. An entry is shown for each role (and schema, if applicable) for which the default privilege settings have been changed from the built-in defaults. If *pattern* is specified, only entries whose role name or schema name matches the pattern are listed.

The ALTER DEFAULT PRIVILEGES command is used to set default access privileges. The meaning of the privilege display is explained under GRANT.

`\dD[S+] [ pattern ]`

Lists domains. If *pattern* is specified, only domains whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If + is appended to the command name, each object is listed with its associated permissions and description.

```
\dE[S+] [ pattern ]
\di[S+] [ pattern ]
\dm[S+] [ pattern ]
\ds[S+] [ pattern ]
\dt[S+] [ pattern ]
\dv[S+] [ pattern ]
```

In this group of commands, the letters `E`, `i`, `m`, `s`, `t`, and `v` stand for foreign table, index, materialized view, sequence, table, and view, respectively. You can specify any or all of these letters, in any order, to obtain a listing of objects of these types. For example, `\dit` lists indexes and tables. If `+` is appended to the command name, each object is listed with its physical size on disk and its associated description, if any. If *`pattern`* is specified, only objects whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

```
\des[+] [ pattern ]
```

Lists foreign servers (mnemonic: "external servers"). If *`pattern`* is specified, only those servers whose name matches the pattern are listed. If the form `\des+` is used, a full description of each server is shown, including the server's ACL, type, version, options, and description.

```
\det[+] [ pattern ]
```

Lists foreign tables (mnemonic: "external tables"). If *`pattern`* is specified, only entries whose table name or schema name matches the pattern are listed. If the form `\det+` is used, generic options and the foreign table description are also displayed.

```
\deu[+] [ pattern ]
```

Lists user mappings (mnemonic: "external users"). If *`pattern`* is specified, only those mappings whose user names match the pattern are listed. If the form `\deu+` is used, additional information about each mapping is shown.

Caution

`\deu+` might also display the user name and password of the remote user, so care should be taken not to disclose them.

```
\dew[+] [ pattern ]
```

Lists foreign-data wrappers (mnemonic: "external wrappers"). If *`pattern`* is specified, only those foreign-data wrappers whose name matches the pattern are listed. If the form `\dew+` is used, the ACL, options, and description of the foreign-data wrapper are also shown.

```
\df[antwS+] [ pattern ]
```

Lists functions, together with their arguments, return types, and function types, which are classified as "agg" (aggregate), "normal", "trigger", or "window". To display only functions of specific type(s), add the corresponding letters `a`, `n`, `t`, or `w` to the command. If *`pattern`* is specified, only functions whose names match the pattern are shown. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If the form `\df+` is used, additional information about each function is shown, including security classification, volatility, owner, language, source code and description.

Tip: To look up functions taking arguments or returning values of a specific type, use your pager's search capability to scroll through the `\df` output.

`\dF[+] [ pattern ]`

Lists text search configurations. If *pattern* is specified, only configurations whose names match the pattern are shown. If the form `\dF+` is used, a full description of each configuration is shown, including the underlying text search parser and the dictionary list for each parser token type.

`\dFd[+] [ pattern ]`

Lists text search dictionaries. If *pattern* is specified, only dictionaries whose names match the pattern are shown. If the form `\dFd+` is used, additional information is shown about each selected dictionary, including the underlying text search template and the option values.

`\dFp[+] [ pattern ]`

Lists text search parsers. If *pattern* is specified, only parsers whose names match the pattern are shown. If the form `\dFp+` is used, a full description of each parser is shown, including the underlying functions and the list of recognized token types.

`\dFt[+] [ pattern ]`

Lists text search templates. If *pattern* is specified, only templates whose names match the pattern are shown. If the form `\dFt+` is used, additional information is shown about each template, including the underlying function names.

`\dg[+] [ pattern ]`

Lists database roles. (Since the concepts of "users" and "groups" have been unified into "roles", this command is now equivalent to `\du`.) If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\dg+` is used, additional information is shown about each role; currently this adds the comment for each role.

`\dl`

This is an alias for `\lo_list`, which shows a list of large objects.

`\dL[S+] [ pattern ]`

Lists procedural languages. If *pattern* is specified, only languages whose names match the pattern are listed. By default, only user-created languages are shown; supply the `S` modifier to include system objects. If `+` is appended to the command name, each language is listed with its call handler, validator, access privileges, and whether it is a system object.

`\dn[S+] [ pattern ]`

Lists schemas (namespaces). If *pattern* is specified, only schemas whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each object is listed with its associated permissions and description, if any.

`\do[S+] [ pattern ]`

Lists operators with their operand and result types. If *pattern* is specified, only operators whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, additional information about each operator is shown, currently just the name of the underlying function.

`\dO[S+] [ pattern ]`

Lists collations. If *pattern* is specified, only collations whose names match the pattern are listed. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects. If `+` is appended to the command name, each collation is listed with

its associated description, if any. Note that only collations usable with the current database's encoding are shown, so the results may vary in different databases of the same installation.

`\dp [ pattern ]`

Lists tables, views and sequences with their associated access privileges. If *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

The GRANT and REVOKE commands are used to set access privileges. The meaning of the privilege display is explained under GRANT.

`\drds [ role-pattern [ database-pattern ] ]`

Lists defined configuration settings. These settings can be role-specific, database-specific, or both. *role-pattern* and *database-pattern* are used to select specific roles and databases to list, respectively. If omitted, or if * is specified, all settings are listed, including those not role-specific or database-specific, respectively.

The ALTER ROLE and ALTER DATABASE commands are used to define per-role and per-database configuration settings.

`\dT[S+] [ pattern ]`

Lists data types. If *pattern* is specified, only types whose names match the pattern are listed. If + is appended to the command name, each type is listed with its internal name and size, its allowed values if it is an `enum` type, and its associated permissions. By default, only user-created objects are shown; supply a pattern or the `S` modifier to include system objects.

`\du[+] [ pattern ]`

Lists database roles. (Since the concepts of "users" and "groups" have been unified into "roles", this command is now equivalent to `\dg`.) If *pattern* is specified, only those roles whose names match the pattern are listed. If the form `\du+` is used, additional information is shown about each role; currently this adds the comment for each role.

`\dx[+] [ pattern ]`

Lists installed extensions. If *pattern* is specified, only those extensions whose names match the pattern are listed. If the form `\dx+` is used, all the objects belonging to each matching extension are listed.

`\dy[+] [ pattern ]`

Lists event triggers. If *pattern* is specified, only those event triggers whose names match the pattern are listed. If + is appended to the command name, each object is listed with its associated description.

`\e` or `\edit [ filename ] [ line_number ]`

If *filename* is specified, the file is edited; after the editor exits, its content is copied back to the query buffer. If no *filename* is given, the current query buffer is copied to a temporary file which is then edited in the same fashion.

The new query buffer is then re-parsed according to the normal rules of psql, where the whole buffer is treated as a single line. (Thus you cannot make scripts this way. Use `\i` for that.) This means that if the query ends with (or contains) a semicolon, it is immediately executed. Otherwise it will merely wait in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

If a line number is specified, psql will position the cursor on the specified line of the file or query buffer. Note that if a single all-digits argument is given, psql assumes it is a line number, not a file name.

Tip: See under *Environment* for how to configure and customize your editor.

`\echo` *text* `[ ... ]`

Prints the arguments to the standard output, separated by one space and followed by a newline. This can be useful to intersperse information in the output of scripts. For example:

```
=> \echo `date`
Tue Oct 26 21:40:57 CEST 1999
```

If the first argument is an unquoted `-n` the trailing newline is not written.

Tip: If you use the `\o` command to redirect your query output you might wish to use `\qecho` instead of this command.

`\ef [` *function_description* `[` *line_number* `] ]`

This command fetches and edits the definition of the named function, in the form of a `CREATE OR REPLACE FUNCTION` command. Editing is done in the same way as for `\edit`. After the editor exits, the updated command waits in the query buffer; type semicolon or `\g` to send it, or `\r` to cancel.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If no function is specified, a blank `CREATE FUNCTION` template is presented for editing.

If a line number is specified, psql will position the cursor on the specified line of the function body. (Note that the function body typically does not begin on the first line of the file.)

Tip: See under *Environment* for how to configure and customize your editor.

`\encoding [` *encoding* `]`

Sets the client character set encoding. Without an argument, this command shows the current encoding.

`\f [` *string* `]`

Sets the field separator for unaligned query output. The default is the vertical bar (`|`). See also `\pset` for a generic way of setting output options.

`\g [` *filename* `]`
`\g [ |`*command* `]`

Sends the current query input buffer to the server, and optionally stores the query's output in *filename* or pipes the output to the shell command *command*. The file or command is written to only if the query successfully returns zero or more tuples, not if the query fails or is a non-data-returning SQL command.

A bare `\g` is essentially equivalent to a semicolon. A `\g` with argument is a "one-shot" alternative to the `\o` command.

`\gset [ prefix ]`

Sends the current query input buffer to the server and stores the query's output into psql variables (see *Variables*). The query to be executed must return exactly one row. Each column of the row is stored into a separate variable, named the same as the column. For example:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset
=> \echo :var1 :var2
hello 10
```

If you specify a *prefix*, that string is prepended to the query's column names to create the variable names to use:

```
=> SELECT 'hello' AS var1, 10 AS var2
-> \gset result_
=> \echo :result_var1 :result_var2
hello 10
```

If a column result is NULL, the corresponding variable is unset rather than being set.

If the query fails or does not return one row, no variables are changed.

`\h` or `\help [ command ]`

Gives syntax help on the specified SQL command. If *command* is not specified, then psql will list all the commands for which syntax help is available. If *command* is an asterisk (`*`), then syntax help on all SQL commands is shown.

> **Note:** To simplify typing, commands that consists of several words do not have to be quoted. Thus it is fine to type **`\help alter table`**.

`\H` or `\html`

Turns on HTML query output format. If the HTML format is already on, it is switched back to the default aligned text format. This command is for compatibility and convenience, but see `\pset` about setting other output options.

`\i` or `\include` *filename*

Reads input from the file *filename* and executes it as though it had been typed on the keyboard.

> **Note:** If you want to see the lines on the screen as they are read you must set the variable `ECHO` to `all`.

`\ir` or `\include_relative` *filename*

The `\ir` command is similar to `\i`, but resolves relative file names differently. When executing in interactive mode, the two commands behave identically. However, when invoked from a script, `\ir` interprets file names relative to the directory in which the script is located, rather than the current working directory.

`\l[+]` or `\list[+] [ pattern ]`

List the databases in the server and show their names, owners, character set encodings, and access privileges. If *pattern* is specified, only databases whose names match the pattern are listed. If + is appended to the command name, database sizes, default tablespaces, and descriptions are also displayed. (Size information is only available for databases that the current user can connect to.)

`\lo_export` *loid filename*

Reads the large object with OID *loid* from the database and writes it to *filename*. Note that this is subtly different from the server function `lo_export`, which acts with the permissions of the user that the database server runs as and on the server's file system.

Tip: Use `\lo_list` to find out the large object's OID.

`\lo_import` *filename* [*comment*]

Stores the file into a PostgreSQL large object. Optionally, it associates the given comment with the object. Example:

```
foo=> \lo_import '/home/peter/pictures/photo.xcf' 'a picture of me'
lo_import 152801
```

The response indicates that the large object received object ID 152801, which can be used to access the newly-created large object in the future. For the sake of readability, it is recommended to always associate a human-readable comment with every object. Both OIDs and comments can be viewed with the `\lo_list` command.

Note that this command is subtly different from the server-side `lo_import` because it acts as the local user on the local file system, rather than the server's user and file system.

`\lo_list`

Shows a list of all PostgreSQL large objects currently stored in the database, along with any comments provided for them.

`\lo_unlink` *loid*

Deletes the large object with OID *loid* from the database.

Tip: Use `\lo_list` to find out the large object's OID.

`\o` or `\out` [*filename*]
`\o` or `\out` [|*command*]

Arranges to save future query results to the file *filename* or pipe future results to the shell command *command*. If no argument is specified, the query output is reset to the standard output.

"Query results" includes all tables, command responses, and notices obtained from the database server, as well as output of various backslash commands that query the database (such as `\d`), but not error messages.

Tip: To intersperse text output in between query results, use `\qecho`.

`\p` or `\print`

Print the current query buffer to the standard output.

`\password` [*username*]

Changes the password of the specified user (by default, the current user). This command prompts for the new password, encrypts it, and sends it to the server as an `ALTER ROLE` command. This makes sure that the new password does not appear in cleartext in the command history, the server log, or elsewhere.

`\prompt [ text ] name`

Prompts the user to supply text, which is assigned to the variable *name*. An optional prompt string, *text*, can be specified. (For multiword prompts, surround the text with single quotes.)

By default, `\prompt` uses the terminal for input and output. However, if the `-f` command line switch was used, `\prompt` uses standard input and standard output.

`\pset [ option [ value ] ]`

This command sets options affecting the output of query result tables. *option* indicates which option is to be set. The semantics of *value* vary depending on the selected option. For some options, omitting *value* causes the option to be toggled or unset, as described under the particular option. If no such behavior is mentioned, then omitting *value* just results in the current setting being displayed.

`\pset` without any arguments displays the current status of all printing options.

Adjustable printing options are:

`border`

The *value* must be a number. In general, the higher the number the more borders and lines the tables will have, but this depends on the particular format. In HTML format, this will translate directly into the `border=...` attribute; in the other formats only values 0 (no border), 1 (internal dividing lines), and 2 (table frame) make sense. `latex` and `latex-longtable` also support a `border` value of 3 which adds a dividing line between each row.

`columns`

Sets the target width for the `wrapped` format, and also the width limit for determining whether output is wide enough to require the pager or switch to the vertical display in expanded auto mode. Zero (the default) causes the target width to be controlled by the environment variable `COLUMNS`, or the detected screen width if `COLUMNS` is not set. In addition, if `columns` is zero then the `wrapped` format only affects screen output. If `columns` is nonzero then file and pipe output is wrapped to that width as well.

`expanded` (or `x`)

If *value* is specified it must be either `on` or `off`, which will enable or disable expanded mode, or `auto`. If *value* is omitted the command toggles between the on and off settings. When expanded mode is enabled, query results are displayed in two columns, with the column name on the left and the data on the right. This mode is useful if the data wouldn't fit on the screen in the normal "horizontal" mode. In the auto setting, the expanded mode is used whenever the query output is wider than the screen, otherwise the regular mode is used. The auto setting is only effective in the aligned and wrapped formats. In other formats, it always behaves as if the expanded mode is off.

`fieldsep`

Specifies the field separator to be used in unaligned output format. That way one can create, for example, tab- or comma-separated output, which other programs might prefer. To set a tab as field separator, type `\pset fieldsep '\t'`. The default field separator is `'|'` (a vertical bar).

`fieldsep_zero`

Sets the field separator to use in unaligned output format to a zero byte.

`footer`

If *`value`* is specified it must be either `on` or `off` which will enable or disable display of the table footer (the `(`*`n`*` rows)` count). If *`value`* is omitted the command toggles footer display on or off.

`format`

Sets the output format to one of `unaligned`, `aligned`, `wrapped`, `html`, `latex` (uses `tabular`), `latex-longtable`, or `troff-ms`. Unique abbreviations are allowed. (That would mean one letter is enough.)

`unaligned` format writes all columns of a row on one line, separated by the currently active field separator. This is useful for creating output that might be intended to be read in by other programs (for example, tab-separated or comma-separated format).

`aligned` format is the standard, human-readable, nicely formatted text output; this is the default.

`wrapped` format is like `aligned` but wraps wide data values across lines to make the output fit in the target column width. The target width is determined as described under the `columns` option. Note that psql will not attempt to wrap column header titles; therefore, `wrapped` format behaves the same as `aligned` if the total width needed for column headers exceeds the target.

The `html`, `latex`, `latex-longtable`, and `troff-ms` formats put out tables that are intended to be included in documents using the respective mark-up language. They are not complete documents! This might not be necessary in HTML, but in LaTeX you must have a complete document wrapper. `latex-longtable` also requires the LaTeX `longtable` and `booktabs` packages.

`linestyle`

Sets the border line drawing style to one of `ascii`, `old-ascii` or `unicode`. Unique abbreviations are allowed. (That would mean one letter is enough.) The default setting is `ascii`. This option only affects the `aligned` and `wrapped` output formats.

`ascii` style uses plain ASCII characters. Newlines in data are shown using a `+` symbol in the right-hand margin. When the `wrapped` format wraps data from one line to the next without a newline character, a dot (`.`) is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

`old-ascii` style uses plain ASCII characters, using the formatting style used in PostgreSQL 8.4 and earlier. Newlines in data are shown using a `:` symbol in place of the left-hand column separator. When the data is wrapped from one line to the next without a newline character, a `;` symbol is used in place of the left-hand column separator.

`unicode` style uses Unicode box-drawing characters. Newlines in data are shown using a carriage return symbol in the right-hand margin. When the data is wrapped from one line to the next without a newline character, an ellipsis symbol is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

When the `border` setting is greater than zero, this option also determines the characters with which the border lines are drawn. Plain ASCII characters work everywhere, but Unicode characters look nicer on displays that recognize them.

`null`

Sets the string to be printed in place of a null value. The default is to print nothing, which can easily be mistaken for an empty string. For example, one might prefer `\pset null '(null)'`.

`numericlocale`

If *`value`* is specified it must be either `on` or `off` which will enable or disable display of a locale-specific character to separate groups of digits to the left of the decimal marker. If *`value`* is omitted the command toggles between regular and locale-specific numeric output.

`pager`

Controls use of a pager program for query and psql help output. If the environment variable `PAGER` is set, the output is piped to the specified program. Otherwise a platform-dependent default (such as `more`) is used.

When the `pager` option is `off`, the pager program is not used. When the `pager` option is `on`, the pager is used when appropriate, i.e., when the output is to a terminal and will not fit on the screen. The `pager` option can also be set to `always`, which causes the pager to be used for all terminal output regardless of whether it fits on the screen. `\pset pager` without a *`value`* toggles pager use on and off.

`recordsep`

Specifies the record (line) separator to use in unaligned output format. The default is a newline character.

`recordsep_zero`

Sets the record separator to use in unaligned output format to a zero byte.

`tableattr` (or `T`)

In HTML format, this specifies attributes to be placed inside the `table` tag. This could for example be `cellpadding` or `bgcolor`. Note that you probably don't want to specify `border` here, as that is already taken care of by `\pset border`. If no *`value`* is given, the table attributes are unset.

In `latex-longtable` format, this controls the proportional width of each column containing a left-aligned data type. It is specified as a whitespace-separated list of values, e.g. `'0.2 0.2 0.6'`. Unspecified output columns use the last specified value.

`title`

Sets the table title for any subsequently printed tables. This can be used to give your output descriptive tags. If no *`value`* is given, the title is unset.

`tuples_only` (or `t`)

If *`value`* is specified it must be either `on` or `off` which will enable or disable tuples-only mode. If *`value`* is omitted the command toggles between regular and tuples-only output. Regular output includes extra information such as column headers, titles, and various footers. In tuples-only mode, only actual table data is shown.

Illustrations of how these different formats look can be seen in the *Examples* section.

Tip: There are various shortcut commands for `\pset`. See `\a`, `\C`, `\H`, `\t`, `\T`, and `\x`.

`\q` or `\quit`

Quits the psql program. In a script file, only execution of that script is terminated.

`\qecho` *text* [...]

This command is identical to `\echo` except that the output will be written to the query output channel, as set by `\o`.

`\r` or `\reset`

Resets (clears) the query buffer.

`\s` [*filename*]

Print psql's command line history to *filename*. If *filename* is omitted, the history is written to the standard output (using the pager if appropriate). This command is not available if psql was built without Readline support.

`\set` [*name* [*value* [...]]]

Sets the psql variable *name* to *value*, or if more than one value is given, to the concatenation of all of them. If only one argument is given, the variable is set with an empty value. To unset a variable, use the `\unset` command.

`\set` without any arguments displays the names and values of all currently-set psql variables.

Valid variable names can contain letters, digits, and underscores. See the section *Variables* below for details. Variable names are case-sensitive.

Although you are welcome to set any variable to anything you want, psql treats several variables as special. They are documented in the section about variables.

Note: This command is unrelated to the SQL command SET.

`\setenv` *name* [*value*]

Sets the environment variable *name* to *value*, or if the *value* is not supplied, unsets the environment variable. Example:

```
testdb=> \setenv PAGER less
testdb=> \setenv LESS -imx4F
```

`\sf[+]` *function_description*

This command fetches and shows the definition of the named function, in the form of a `CREATE OR REPLACE FUNCTION` command. The definition is printed to the current query output channel, as set by `\o`.

The target function can be specified by name alone, or by name and arguments, for example `foo(integer, text)`. The argument types must be given if there is more than one function of the same name.

If + is appended to the command name, then the output lines are numbered, with the first line of the function body being line 1.

`\t`

Toggles the display of output column name headings and row count footer. This command is equivalent to `\pset tuples_only` and is provided for convenience.

`\T` *table_options*

Specifies attributes to be placed within the `table` tag in HTML output format. This command is equivalent to `\pset tableattr` *table_options*.

`\timing [ on | off ]`

Without parameter, toggles a display of how long each SQL statement takes, in milliseconds. With parameter, sets same.

`\unset name`

Unsets (deletes) the psql variable *name*.

`\w` or `\write filename`
`\w` or `\write |command`

Outputs the current query buffer to the file *filename* or pipes it to the shell command *command*.

`\watch [ seconds ]`

Repeatedly execute the current query buffer (like `\g`) until interrupted or the query fails. Wait the specified number of seconds (default 2) between executions.

`\x [ on | off | auto ]`

Sets or toggles expanded table formatting mode. As such it is equivalent to `\pset expanded`.

`\z [ pattern ]`

Lists tables, views and sequences with their associated access privileges. If a *pattern* is specified, only tables, views and sequences whose names match the pattern are listed.

This is an alias for `\dp` ("display privileges").

`\! [ command ]`

Escapes to a separate shell or executes the shell command *command*. The arguments are not further interpreted; the shell will see them as-is. In particular, the variable substitution rules and backslash escapes do not apply.

`\?`

Shows help information about the backslash commands.

Patterns

The various `\d` commands accept a *pattern* parameter to specify the object name(s) to be displayed. In the simplest case, a pattern is just the exact name of the object. The characters within a pattern are normally folded to lower case, just as in SQL names; for example, `\dt FOO` will display the table named `foo`. As in SQL names, placing double quotes around a pattern stops folding to lower case. Should you need to include an actual double quote character in a pattern, write it as a pair of double quotes within a double-quote sequence; again this is in accord with the rules for SQL quoted identifiers. For example, `\dt "FOO""BAR"` will display the table named `FOO"BAR` (not `foo"bar`). Unlike the normal rules for SQL names, you can put double quotes around just part of a pattern, for instance `\dt FOO"FOO"BAR` will display the table named `fooFOObar`.

Whenever the *pattern* parameter is omitted completely, the `\d` commands display all objects that are visible in the current schema search path — this is equivalent to using `*` as the pattern. (An object is said to be *visible* if its containing schema is in the search path and no object of the same kind and name appears earlier in the search path. This is equivalent to the statement that the object can be referenced by name without explicit schema qualification.) To see all objects in the database regardless of visibility, use `*.*` as the pattern.

Within a pattern, `*` matches any sequence of characters (including no characters) and `?` matches any single character. (This notation is comparable to Unix shell file name patterns.) For example, `\dt`

`int*` displays tables whose names begin with `int`. But within double quotes, `*` and `?` lose these special meanings and are just matched literally.

A pattern that contains a dot (`.`) is interpreted as a schema name pattern followed by an object name pattern. For example, `\dt foo*.*bar*` displays all tables whose table name includes `bar` that are in schemas whose schema name starts with `foo`. When no dot appears, then the pattern matches only objects that are visible in the current schema search path. Again, a dot within double quotes loses its special meaning and is matched literally.

Advanced users can use regular-expression notations such as character classes, for example `[0-9]` to match any digit. All regular expression special characters work as specified in Section 9.7.3, except for `.` which is taken as a separator as mentioned above, `*` which is translated to the regular-expression notation `.*`, `?` which is translated to `.`, and `$` which is matched literally. You can emulate these pattern characters at need by writing `?` for `.`, `(R+|)` for *R*`*`, or `(R|)` for *R*`?`. `$` is not needed as a regular-expression character since the pattern must match the whole name, unlike the usual interpretation of regular expressions (in other words, `$` is automatically appended to your pattern). Write `*` at the beginning and/or end if you don't wish the pattern to be anchored. Note that within double quotes, all regular expression special characters lose their special meanings and are matched literally. Also, the regular expression special characters are matched literally in operator name patterns (i.e., the argument of `\do`).

Advanced Features

Variables

psql provides variable substitution features similar to common Unix command shells. Variables are simply name/value pairs, where the value can be any string of any length. The name must consist of letters (including non-Latin letters), digits, and underscores.

To set a variable, use the psql meta-command `\set`. For example,

```
testdb=> \set foo bar
```

sets the variable `foo` to the value `bar`. To retrieve the content of the variable, precede the name with a colon, for example:

```
testdb=> \echo :foo
bar
```

This works in both regular SQL commands and meta-commands; there is more detail in *SQL Interpolation*, below.

If you call `\set` without a second argument, the variable is set, with an empty string as value. To unset (i.e., delete) a variable, use the command `\unset`. To show the values of all variables, call `\set` without any argument.

> **Note:** The arguments of `\set` are subject to the same substitution rules as with other commands. Thus you can construct interesting references such as `\set :foo 'something'` and get "soft links" or "variable variables" of Perl or PHP fame, respectively. Unfortunately (or fortunately?), there is no way to do anything useful with these constructs. On the other hand, `\set bar :foo` is a perfectly valid way to copy a variable.

A number of these variables are treated specially by psql. They represent certain option settings that can be changed at run time by altering the value of the variable, or in some cases represent changeable state of psql. Although you can use these variables for other purposes, this is not recommended, as the program behavior might grow really strange really quickly. By convention, all specially treated variables' names consist of all upper-case ASCII letters (and possibly digits and underscores). To ensure maximum compatibility in the future, avoid using such variable names for your own purposes. A list of all specially treated variables follows.

`AUTOCOMMIT`

When `on` (the default), each SQL command is automatically committed upon successful completion. To postpone commit in this mode, you must enter a `BEGIN` or `START TRANSACTION` SQL command. When `off` or unset, SQL commands are not committed until you explicitly issue `COMMIT` or `END`. The autocommit-off mode works by issuing an implicit `BEGIN` for you, just before any command that is not already in a transaction block and is not itself a `BEGIN` or other transaction-control command, nor a command that cannot be executed inside a transaction block (such as `VACUUM`).

Note: In autocommit-off mode, you must explicitly abandon any failed transaction by entering `ABORT` or `ROLLBACK`. Also keep in mind that if you exit the session without committing, your work will be lost.

Note: The autocommit-on mode is PostgreSQL's traditional behavior, but autocommit-off is closer to the SQL spec. If you prefer autocommit-off, you might wish to set it in the system-wide `psqlrc` file or your `~/.psqlrc` file.

`COMP_KEYWORD_CASE`

Determines which letter case to use when completing an SQL key word. If set to `lower` or `upper`, the completed word will be in lower or upper case, respectively. If set to `preserve-lower` or `preserve-upper` (the default), the completed word will be in the case of the word already entered, but words being completed without anything entered will be in lower or upper case, respectively.

`DBNAME`

The name of the database you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

`ECHO`

If set to `all`, all nonempty input lines are printed to standard output as they are read. (This does not apply to lines read interactively.) To select this behavior on program start-up, use the switch `-a`. If set to `queries`, psql prints each query to standard output as it is sent to the server. The switch for this is `-e`.

`ECHO_HIDDEN`

When this variable is set to `on` and a backslash command queries the database, the query is first shown. This feature helps you to study PostgreSQL internals and provide similar functionality in your own programs. (To select this behavior on program start-up, use the switch `-E`.) If you set the variable to the value `noexec`, the queries are just shown but are not actually sent to the server and executed.

`ENCODING`

The current client character set encoding.

`FETCH_COUNT`

If this variable is set to an integer value > 0, the results of `SELECT` queries are fetched and displayed in groups of that many rows, rather than the default behavior of collecting the entire result set before display. Therefore only a limited amount of memory is used, regardless of the size of the result set. Settings of 100 to 1000 are commonly used when enabling this feature. Keep in mind that when using this feature, a query might fail after having already displayed some rows.

> **Tip:** Although you can use any output format with this feature, the default `aligned` format tends to look bad because each group of `FETCH_COUNT` rows will be formatted separately, leading to varying column widths across the row groups. The other output formats work better.

`HISTCONTROL`

If this variable is set to `ignorespace`, lines which begin with a space are not entered into the history list. If set to a value of `ignoredups`, lines matching the previous history line are not entered. A value of `ignoreboth` combines the two options. If unset, or if set to any other value than those above, all lines read in interactive mode are saved on the history list.

> **Note:** This feature was shamelessly plagiarized from Bash.

`HISTFILE`

The file name that will be used to store the history list. The default value is `~/.psql_history`. For example, putting:

```
\set HISTFILE ~/.psql_history- :DBNAME
```

in `~/.psqlrc` will cause psql to maintain a separate history for each database.

> **Note:** This feature was shamelessly plagiarized from Bash.

`HISTSIZE`

The number of commands to store in the command history. The default value is 500.

> **Note:** This feature was shamelessly plagiarized from Bash.

`HOST`

The database server host you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

`IGNOREEOF`

If unset, sending an EOF character (usually **Control+D**) to an interactive session of psql will terminate the application. If set to a numeric value, that many EOF characters are ignored before the application terminates. If the variable is set but has no numeric value, the default is 10.

Note: This feature was shamelessly plagiarized from Bash.

`LASTOID`

The value of the last affected OID, as returned from an `INSERT` or `\lo_import` command. This variable is only guaranteed to be valid until after the result of the next SQL command has been displayed.

`ON_ERROR_ROLLBACK`

When set to `on`, if a statement in a transaction block generates an error, the error is ignored and the transaction continues. When set to `interactive`, such errors are only ignored in interactive sessions, and not when reading script files. When unset or set to `off`, a statement in a transaction block that generates an error aborts the entire transaction. The error rollback mode works by issuing an implicit `SAVEPOINT` for you, just before each command that is in a transaction block, and then rolling back to the savepoint if the command fails.

`ON_ERROR_STOP`

By default, command processing continues after an error. When this variable is set to `on`, processing will instead stop immediately. In interactive mode, psql will return to the command prompt; otherwise, psql will exit, returning error code 3 to distinguish this case from fatal error conditions, which are reported using error code 1. In either case, any currently running scripts (the top-level script, if any, and any other scripts which it may have in invoked) will be terminated immediately. If the top-level command string contained multiple SQL commands, processing will stop with the current command.

`PORT`

The database server port to which you are currently connected. This is set every time you connect to a database (including program start-up), but can be unset.

`PROMPT1`
`PROMPT2`
`PROMPT3`

These specify what the prompts psql issues should look like. See *Prompting* below.

`QUIET`

Setting this variable to `on` is equivalent to the command line option `-q`. It is probably not too useful in interactive mode.

`SINGLELINE`

Setting this variable to `on` is equivalent to the command line option `-S`.

`SINGLESTEP`

Setting this variable to `on` is equivalent to the command line option `-s`.

`USER`

The database user you are currently connected as. This is set every time you connect to a database (including program start-up), but can be unset.

`VERBOSITY`

This variable can be set to the values `default`, `verbose`, or `terse` to control the verbosity of error reports.

SQL Interpolation

A key feature of psql variables is that you can substitute ("interpolate") them into regular SQL statements, as well as the arguments of meta-commands. Furthermore, psql provides facilities for ensuring that variable values used as SQL literals and identifiers are properly quoted. The syntax for interpolating a value without any quoting is to prepend the variable name with a colon (`:`). For example,

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :foo;
```

would query the table `my_table`. Note that this may be unsafe: the value of the variable is copied literally, so it can contain unbalanced quotes, or even backslash commands. You must make sure that it makes sense where you put it.

When a value is to be used as an SQL literal or identifier, it is safest to arrange for it to be quoted. To quote the value of a variable as an SQL literal, write a colon followed by the variable name in single quotes. To quote the value as an SQL identifier, write a colon followed by the variable name in double quotes. These constructs deal correctly with quotes and other special characters embedded within the variable value. The previous example would be more safely written this way:

```
testdb=> \set foo 'my_table'
testdb=> SELECT * FROM :"foo";
```

Variable interpolation will not be performed within quoted SQL literals and identifiers. Therefore, a construction such as `':foo'` doesn't work to produce a quoted literal from a variable's value (and it would be unsafe if it did work, since it wouldn't correctly handle quotes embedded in the value).

One example use of this mechanism is to copy the contents of a file into a table column. First load the file into a variable and then interpolate the variable's value as a quoted string:

```
testdb=> \set content `cat my_file.txt`
testdb=> INSERT INTO my_table VALUES (:'content');
```

(Note that this still won't work if `my_file.txt` contains NUL bytes. psql does not support embedded NUL bytes in variable values.)

Since colons can legally appear in SQL commands, an apparent attempt at interpolation (that is, `:name`, `:'name'`, or `:"name"`) is not replaced unless the named variable is currently set. In any case, you can escape a colon with a backslash to protect it from substitution.

The colon syntax for variables is standard SQL for embedded query languages, such as ECPG. The colon syntaxes for array slices and type casts are PostgreSQL extensions, which can sometimes conflict with the standard usage. The colon-quote syntax for escaping a variable's value as an SQL literal or identifier is a psql extension.

Prompting

The prompts psql issues can be customized to your preference. The three variables `PROMPT1`, `PROMPT2`, and `PROMPT3` contain strings and special escape sequences that describe the appearance of the prompt. Prompt 1 is the normal prompt that is issued when psql requests a new command. Prompt 2 is issued when more input is expected during command input because the command was not terminated with a semicolon or a quote was not closed. Prompt 3 is issued when you run an SQL `COPY` command and you are expected to type in the row values on the terminal.

The value of the selected prompt variable is printed literally, except where a percent sign (`%`) is encountered. Depending on the next character, certain other text is substituted instead. Defined substitutions are:

`%M`

The full host name (with domain name) of the database server, or `[local]` if the connection is over a Unix domain socket, or `[local:`*`/dir/name`*`]`, if the Unix domain socket is not at the compiled in default location.

`%m`

The host name of the database server, truncated at the first dot, or `[local]` if the connection is over a Unix domain socket.

`%>`

The port number at which the database server is listening.

`%n`

The database session user name. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%/`

The name of the current database.

`%~`

Like `%/`, but the output is `~` (tilde) if the database is your default database.

`%#`

If the session user is a database superuser, then a `#`, otherwise a `>`. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)

`%R`

In prompt 1 normally `=`, but `^` if in single-line mode, and `!` if the session is disconnected from the database (which can happen if `\connect` fails). In prompt 2 the sequence is replaced by `-`, `*`, a single quote, a double quote, or a dollar sign, depending on whether psql expects more input because the command wasn't terminated yet, because you are inside a `/* ... */` comment, or because you are inside a quoted or dollar-escaped string. In prompt 3 the sequence doesn't produce anything.

`%x`

Transaction status: an empty string when not in a transaction block, or `*` when in a transaction block, or `!` when in a failed transaction block, or `?` when the transaction state is indeterminate (for example, because there is no connection).

`%`*`digits`*

The character with the indicated octal code is substituted.

`%:`*`name`*`:`

The value of the psql variable *`name`*. See the section *Variables* for details.

`%`` `*`command`*` `` `

The output of *`command`*, similar to ordinary "back-tick" substitution.

`%[ ... %]`

Prompts can contain terminal control characters which, for example, change the color, background, or style of the prompt text, or change the title of the terminal window. In order for the line editing features of Readline to work properly, these non-printing control characters must be designated as invisible by surrounding them with `%[` and `%]`. Multiple pairs of these can occur within the prompt. For example:

```
testdb=> \set PROMPT1 '%[%033[1;33;40m%]%n@%/%R%[%033[0m%]%# '
```

results in a boldfaced (`1;`) yellow-on-black (`33;40`) prompt on VT100-compatible, color-capable terminals.

To insert a percent sign into your prompt, write `%%`. The default prompts are `'%/%R%# '` for prompts 1 and 2, and `'>> '` for prompt 3.

Note: This feature was shamelessly plagiarized from tcsh.

Command-Line Editing

psql supports the Readline library for convenient line editing and retrieval. The command history is automatically saved when psql exits and is reloaded when psql starts up. Tab-completion is also supported, although the completion logic makes no claim to be an SQL parser. The queries generated by tab-completion can also interfere with other SQL commands, e.g. `SET TRANSACTION ISOLATION LEVEL`. If for some reason you do not like the tab completion, you can turn it off by putting this in a file named `.inputrc` in your home directory:

```
$if psql
set disable-completion on
$endif
```

(This is not a psql but a Readline feature. Read its documentation for further details.)

Environment

`COLUMNS`

If `\pset columns` is zero, controls the width for the `wrapped` format and width for determining if wide output requires the pager or should be switched to the vertical format in expanded auto mode.

`PAGER`

If the query results do not fit on the screen, they are piped through this command. Typical values are `more` or `less`. The default is platform-dependent. The use of the pager can be disabled by using the `\pset` command.

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters (see Section 31.14).

`PSQL_EDITOR`
`EDITOR`
`VISUAL`

Editor used by the `\e` and `\ef` commands. The variables are examined in the order listed; the first that is set is used.

The built-in default editors are `vi` on Unix systems and `notepad.exe` on Windows systems.

`PSQL_EDITOR_LINENUMBER_ARG`

When `\e` or `\ef` is used with a line number argument, this variable specifies the command-line argument used to pass the starting line number to the user's editor. For editors such as Emacs or vi, this is a plus sign. Include a trailing space in the value of the variable if there needs to be space between the option name and the line number. Examples:

```
PSQL_EDITOR_LINENUMBER_ARG='+'
PSQL_EDITOR_LINENUMBER_ARG='--line '
```

The default is `+` on Unix systems (corresponding to the default editor `vi`, and useful for many other common editors); but there is no default on Windows systems.

`PSQL_HISTORY`

Alternative location for the command history file. Tilde (`~`) expansion is performed.

`PSQLRC`

Alternative location of the user's `.psqlrc` file. Tilde (`~`) expansion is performed.

`SHELL`

Command executed by the `\!` command.

`TMPDIR`

Directory for storing temporary files. The default is `/tmp`.

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Files

`psqlrc` and `~/.psqlrc`

Unless it is passed an `-X` or `-c` option, psql attempts to read and execute commands from the system-wide startup file (`psqlrc`) and then the user's personal startup file (`~/.psqlrc`), after connecting to the database but before accepting normal commands. These files can be used to set up the client and/or the server to taste, typically with `\set` and `SET` commands.

The system-wide startup file is named `psqlrc` and is sought in the installation's "system configuration" directory, which is most reliably identified by running `pg_config --sysconfdir`. By default this directory will be `../etc/` relative to the directory containing the PostgreSQL executables. The name of this directory can be set explicitly via the `PGSYSCONFDIR` environment variable.

The user's personal startup file is named `.psqlrc` and is sought in the invoking user's home directory. On Windows, which lacks such a concept, the personal startup file is named `%APPDATA%\postgresql\psqlrc.conf`. The location of the user's startup file can be set explicitly via the `PSQLRC` environment variable.

Both the system-wide startup file and the user's personal startup file can be made psql-version-specific by appending a dash and the PostgreSQL major or minor release number to the file name, for example `~/.psqlrc-9.2` or `~/.psqlrc-9.2.5`. The most specific version-matching file will be read in preference to a non-version-specific file.

`.psql_history`

The command-line history is stored in the file `~/.psql_history`, or `%APPDATA%\postgresql\psql_history` on Windows.

The location of the history file can be set explicitly via the `PSQL_HISTORY` environment variable.

Notes

- In an earlier life psql allowed the first argument of a single-letter backslash command to start directly after the command, without intervening whitespace. As of PostgreSQL 8.4 this is no longer allowed.
- psql works best with servers of the same or an older major version. Backslash commands are particularly likely to fail if the server is of a newer version than psql itself. However, backslash commands of the `\d` family should work with servers of versions back to 7.4, though not necessarily with servers newer than psql itself. The general functionality of running SQL commands and displaying query results should also work with servers of a newer major version, but this cannot be guaranteed in all cases.

  If you want to use psql to connect to several servers of different major versions, it is recommended that you use the newest version of psql. Alternatively, you can keep a copy of psql from each major version around and be sure to use the version that matches the respective server. But in practice, this additional complication should not be necessary.

Notes for Windows Users

psql is built as a "console application". Since the Windows console windows use a different encoding than the rest of the system, you must take special care when using 8-bit characters within psql. If psql detects a problematic console code page, it will warn you at startup. To change the console code page, two things are necessary:

- Set the code page by entering **`cmd.exe /c chcp 1252`**. (1252 is a code page that is appropriate for German; replace it with your value.) If you are using Cygwin, you can put this command in `/etc/profile`.
- Set the console font to `Lucida Console`, because the raster font does not work with the ANSI code page.

Examples

The first example shows how to spread a command over several lines of input. Notice the changing prompt:

```
testdb=> CREATE TABLE my_table (
```

```
testdb(>  first integer not null default 0,
testdb(>  second text)
testdb-> ;
CREATE TABLE
```

Now look at the table definition again:

```
testdb=> \d my_table
             Table "my_table"
 Attribute |  Type   |      Modifier
-----------+---------+--------------------
 first     | integer | not null default 0
 second    | text    |
```

Now we change the prompt to something more interesting:

```
testdb=> \set PROMPT1 '%n@%m %~%R%# '
peter@localhost testdb=>
```

Let's assume you have filled the table with data and want to take a look at it:

```
peter@localhost testdb=> SELECT * FROM my_table;
 first | second
-------+--------
     1 | one
     2 | two
     3 | three
     4 | four
(4 rows)
```

You can display tables in different ways by using the `\pset` command:

```
peter@localhost testdb=> \pset border 2
Border style is 2.
peter@localhost testdb=> SELECT * FROM my_table;
+-------+--------+
| first | second |
+-------+--------+
|     1 | one    |
|     2 | two    |
|     3 | three  |
|     4 | four   |
+-------+--------+
(4 rows)

peter@localhost testdb=> \pset border 0
Border style is 0.
peter@localhost testdb=> SELECT * FROM my_table;
first second
----- ------
    1 one
    2 two
    3 three
    4 four
(4 rows)

peter@localhost testdb=> \pset border 1
Border style is 1.
```

```
peter@localhost testdb=> \pset format unaligned
Output format is unaligned.
peter@localhost testdb=> \pset fieldsep ","
Field separator is ",".
peter@localhost testdb=> \pset tuples_only
Showing only tuples.
peter@localhost testdb=> SELECT second, first FROM my_table;
one,1
two,2
three,3
four,4
```

Alternatively, use the short commands:

```
peter@localhost testdb=> \a \t \x
Output format is aligned.
Tuples only is off.
Expanded display is on.
peter@localhost testdb=> SELECT * FROM my_table;
-[ RECORD 1 ]-
first  | 1
second | one
-[ RECORD 2 ]-
first  | 2
second | two
-[ RECORD 3 ]-
first  | 3
second | three
-[ RECORD 4 ]-
first  | 4
second | four
```

reindexdb

Name

`reindexdb` — reindex a PostgreSQL database

Synopsis

`reindexdb` [*connection-option*...] [`--table` | `-t` *table*] ... [`--index` | `-i` *index*] ... [*dbname*]

`reindexdb` [*connection-option*...] `--all` | `-a`

`reindexdb` [*connection-option*...] `--system` | `-s` [*dbname*]

Description

reindexdb is a utility for rebuilding indexes in a PostgreSQL database.

reindexdb is a wrapper around the SQL command REINDEX. There is no effective difference between reindexing databases via this utility and via other methods for accessing the server.

Options

reindexdb accepts the following command-line arguments:

`-a`
`--all`

Reindex all databases.

`[-d]` *dbname*
`[--dbname=]`*dbname*

Specifies the name of the database to be reindexed. If this is not specified and `-a` (or `--all`) is not used, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used.

`-e`
`--echo`

Echo the commands that reindexdb generates and sends to the server.

`-i` *index*
`--index=`*index*

Recreate *index* only. Multiple indexes can be recreated by writing multiple `-i` switches.

`-q`
`--quiet`

Do not display progress messages.

`-s`
`--system`

Reindex database's system catalogs.

`-t` *`table`*
`--table=`*`table`*

Reindex *`table`* only. Multiple tables can be reindexed by writing multiple `-t` switches.

`-V`
`--version`

Print the reindexdb version and exit.

`-?`
`--help`

Show help about reindexdb command line arguments, and exit.

reindexdb also accepts the following command-line arguments for connection parameters:

`-h` *`host`*
`--host=`*`host`*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *`port`*
`--port=`*`port`*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *`username`*
`--username=`*`username`*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force reindexdb to prompt for a password before connecting to a database.

This option is never essential, since reindexdb will automatically prompt for a password if the server demands password authentication. However, reindexdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=`*`dbname`*

Specifies the name of the database to connect to discover what other databases should be reindexed. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see REINDEX and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

reindexdb might need to connect several times to the PostgreSQL server, asking for a password each time. It is convenient to have a `~/.pgpass` file in such cases. See Section 31.15 for more information.

Examples

To reindex the database `test`:

```
$ reindexdb test
```

To reindex the table `foo` and the index `bar` in a database named `abcd`:

```
$ reindexdb --table foo --index bar abcd
```

See Also

REINDEX

vacuumdb

Name

vacuumdb — garbage-collect and analyze a PostgreSQL database

Synopsis

vacuumdb [*connection-option*...] [*option*...] [--table | -t *table* [(*column* [,...])]] ... [*dbname*]

vacuumdb [*connection-option*...] [*option*...] --all | -a

Description

vacuumdb is a utility for cleaning a PostgreSQL database. vacuumdb will also generate internal statistics used by the PostgreSQL query optimizer.

vacuumdb is a wrapper around the SQL command VACUUM. There is no effective difference between vacuuming and analyzing databases via this utility and via other methods for accessing the server.

Options

vacuumdb accepts the following command-line arguments:

-a
--all

Vacuum all databases.

[-d] *dbname*
[--dbname=]*dbname*

Specifies the name of the database to be cleaned or analyzed. If this is not specified and -a (or --all) is not used, the database name is read from the environment variable PGDATABASE. If that is not set, the user name specified for the connection is used.

-e
--echo

Echo the commands that vacuumdb generates and sends to the server.

-f
--full

Perform "full" vacuuming.

-F
--freeze

Aggressively "freeze" tuples.

`-q`
`--quiet`

Do not display progress messages.

`-t` *`table`* `[ (`*`column`* `[,...]) ]`
`--table=`*`table`* `[ (`*`column`* `[,...]) ]`

Clean or analyze *`table`* only. Column names can be specified only in conjunction with the `--analyze` or `--analyze-only` options. Multiple tables can be vacuumed by writing multiple `-t` switches.

> **Tip:** If you specify columns, you probably have to escape the parentheses from the shell. (See examples below.)

`-v`
`--verbose`

Print detailed information during processing.

`-V`
`--version`

Print the vacuumdb version and exit.

`-z`
`--analyze`

Also calculate statistics for use by the optimizer.

`-Z`
`--analyze-only`

Only calculate statistics for use by the optimizer (no vacuum).

`--analyze-in-stages`

Only calculate statistics for use by the optimizer (no vacuum), like `--analyze-only`. Run several (currently three) stages of analyze with different configuration settings, to produce usable statistics faster.

This option is useful to analyze a database that was newly populated from a restored dump or by `pg_upgrade`. This option will try to create some statistics as fast as possible, to make the database usable, and then produce full statistics in the subsequent stages.

`-?`
`--help`

Show help about vacuumdb command line arguments, and exit.

vacuumdb also accepts the following command-line arguments for connection parameters:

`-h` *`host`*
`--host=`*`host`*

Specifies the host name of the machine on which the server is running. If the value begins with a slash, it is used as the directory for the Unix domain socket.

`-p` *port*
`--port=`*port*

Specifies the TCP port or local Unix domain socket file extension on which the server is listening for connections.

`-U` *username*
`--username=`*username*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`
`--password`

Force vacuumdb to prompt for a password before connecting to a database.

This option is never essential, since vacuumdb will automatically prompt for a password if the server demands password authentication. However, vacuumdb will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

`--maintenance-db=`*dbname*

Specifies the name of the database to connect to discover what other databases should be vacuumed. If not specified, the `postgres` database will be used, and if that does not exist, `template1` will be used.

Environment

`PGDATABASE`
`PGHOST`
`PGPORT`
`PGUSER`

Default connection parameters

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Diagnostics

In case of difficulty, see VACUUM and psql for discussions of potential problems and error messages. The database server must be running at the targeted host. Also, any default connection settings and environment variables used by the libpq front-end library will apply.

Notes

vacuumdb might need to connect several times to the PostgreSQL server, asking for a password each time. It is convenient to have a `~/.pgpass` file in such cases. See Section 31.15 for more information.

Examples

To clean the database `test`:

```
$ vacuumdb test
```

To clean and analyze for the optimizer a database named `bigdb`:

```
$ vacuumdb --analyze bigdb
```

To clean a single table `foo` in a database named `xyzzy`, and analyze a single column `bar` of the table for the optimizer:

```
$ vacuumdb --analyze --verbose --table 'foo(bar)' xyzzy
```

See Also

VACUUM

III. PostgreSQL Server Applications

This part contains reference information for PostgreSQL server applications and support utilities. These commands can only be run usefully on the host where the database server resides. Other utility programs are listed in Reference II, *PostgreSQL Client Applications*.

initdb

Name

initdb — create a new PostgreSQL database cluster

Synopsis

initdb [*option*...] [--pgdata | -D] *directory*

Description

initdb creates a new PostgreSQL database cluster. A database cluster is a collection of databases that are managed by a single server instance.

Creating a database cluster consists of creating the directories in which the database data will live, generating the shared catalog tables (tables that belong to the whole cluster rather than to any particular database), and creating the template1 and postgres databases. When you later create a new database, everything in the template1 database is copied. (Therefore, anything installed in template1 is automatically copied into each database created later.) The postgres database is a default database meant for use by users, utilities and third party applications.

Although initdb will attempt to create the specified data directory, it might not have permission if the parent directory of the desired data directory is root-owned. To initialize in such a setup, create an empty data directory as root, then use chown to assign ownership of that directory to the database user account, then su to become the database user to run initdb.

initdb must be run as the user that will own the server process, because the server needs to have access to the files and directories that initdb creates. Since the server cannot be run as root, you must not run initdb as root either. (It will in fact refuse to do so.)

initdb initializes the database cluster's default locale and character set encoding. The character set encoding, collation order (LC_COLLATE) and character set classes (LC_CTYPE, e.g. upper, lower, digit) can be set separately for a database when it is created. initdb determines those settings for the template1 database, which will serve as the default for all other databases.

To alter the default collation order or character set classes, use the --lc-collate and --lc-ctype options. Collation orders other than C or POSIX also have a performance penalty. For these reasons it is important to choose the right locale when running initdb.

The remaining locale categories can be changed later when the server is started. You can also use --locale to set the default for all locale categories, including collation order and character set classes. All server locale values (lc_*) can be displayed via SHOW ALL. More details can be found in Section 22.1.

To alter the default encoding, use the --encoding. More details can be found in Section 22.3.

Options

`-A` *authmethod*
`--auth=`*authmethod*

This option specifies the authentication method for local users used in `pg_hba.conf` (`host` and `local` lines). Do not use `trust` unless you trust all local users on your system. `trust` is the default for ease of installation.

`--auth-host=`*authmethod*

This option specifies the authentication method for local users via TCP/IP connections used in `pg_hba.conf` (`host` lines).

`--auth-local=`*authmethod*

This option specifies the authentication method for local users via Unix-domain socket connections used in `pg_hba.conf` (`local` lines).

`-D` *directory*
`--pgdata=`*directory*

This option specifies the directory where the database cluster should be stored. This is the only information required by `initdb`, but you can avoid writing it by setting the `PGDATA` environment variable, which can be convenient since the database server (`postgres`) can find the database directory later by the same variable.

`-E` *encoding*
`--encoding=`*encoding*

Selects the encoding of the template database. This will also be the default encoding of any database you create later, unless you override it there. The default is derived from the locale, or `SQL_ASCII` if that does not work. The character sets supported by the PostgreSQL server are described in Section 22.3.1.

`-k`
`--data-checksums`

Use checksums on data pages to help detect corruption by the I/O system that would otherwise be silent. Enabling checksums may incur a noticeable performance penalty. This option can only be set during initialization, and cannot be changed later. If set, checksums are calculated for all objects, in all databases.

`--locale=`*locale*

Sets the default locale for the database cluster. If this option is not specified, the locale is inherited from the environment that `initdb` runs in. Locale support is described in Section 22.1.

`--lc-collate=`*locale*
`--lc-ctype=`*locale*
`--lc-messages=`*locale*
`--lc-monetary=`*locale*
`--lc-numeric=`*locale*
`--lc-time=`*locale*

Like `--locale`, but only sets the locale in the specified category.

`--no-locale`

Equivalent to `--locale=C`.

`-N`
`--nosync`

By default, `initdb` will wait for all files to be written safely to disk. This option causes `initdb` to return without waiting, which is faster, but means that a subsequent operating system crash can leave the data directory corrupt. Generally, this option is useful for testing, but should not be used when creating a production installation.

`--pwfile=`*`filename`*

Makes `initdb` read the database superuser's password from a file. The first line of the file is taken as the password.

`-S`
`--sync-only`

Safely write all database files to disk and exit. This does not perform any of the normal initdb operations.

`-T` *`CFG`*
`--text-search-config=`*`CFG`*

Sets the default text search configuration. See default_text_search_config for further information.

`-U` *`username`*
`--username=`*`username`*

Selects the user name of the database superuser. This defaults to the name of the effective user running `initdb`. It is really not important what the superuser's name is, but one might choose to keep the customary name postgres, even if the operating system user's name is different.

`-W`
`--pwprompt`

Makes `initdb` prompt for a password to give the database superuser. If you don't plan on using password authentication, this is not important. Otherwise you won't be able to use password authentication until you have a password set up.

`-X` *`directory`*
`--xlogdir=`*`directory`*

This option specifies the directory where the transaction log should be stored.

Other, less commonly used, options are also available:

`-d`
`--debug`

Print debugging output from the bootstrap backend and a few other messages of lesser interest for the general public. The bootstrap backend is the program `initdb` uses to create the catalog tables. This option generates a tremendous amount of extremely boring output.

`-L` *`directory`*

Specifies where `initdb` should find its input files to initialize the database cluster. This is normally not necessary. You will be told if you need to specify their location explicitly.

`-n`
`--noclean`

By default, when `initdb` determines that an error prevented it from completely creating the database cluster, it removes any files it might have created before discovering that it cannot finish the job. This option inhibits tidying-up and is thus useful for debugging.

Other options:

`-V`
`--version`

Print the initdb version and exit.

`-?`
`--help`

Show help about initdb command line arguments, and exit.

Environment

`PGDATA`

Specifies the directory where the database cluster is to be stored; can be overridden using the `-D` option.

`TZ`

Specifies the default time zone of the created database cluster. The value should be a full time zone name (see Section 8.5.3).

This utility, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14).

Notes

`initdb` can also be invoked via `pg_ctl initdb`.

See Also

pg_ctl, postgres

pg_controldata

Name

pg_controldata — display control information of a PostgreSQL database cluster

Synopsis

pg_controldata [*option*] [*datadir*]

Description

pg_controldata prints information initialized during initdb, such as the catalog version. It also shows information about write-ahead logging and checkpoint processing. This information is cluster-wide, and not specific to any one database.

This utility can only be run by the user who initialized the cluster because it requires read access to the data directory. You can specify the data directory on the command line, or use the environment variable PGDATA. This utility supports the options -V and --version, which print the pg_controldata version and exit. It also supports options -? and --help, which output the supported arguments.

Environment

PGDATA

Default data directory location

pg_ctl

Name

pg_ctl — initialize, start, stop, or control a PostgreSQL server

Synopsis

```
pg_ctl init[db] [-s] [-D datadir] [-o initdb-options]

pg_ctl start [-w] [-t seconds] [-s] [-D datadir] [-l filename] [-o options] [-p path] [-c]

pg_ctl stop [-W] [-t seconds] [-s] [-D datadir] [-m s[mart]|f[ast]|i[mmediate] ]

pg_ctl restart [-w] [-t seconds] [-s] [-D datadir] [-c] [-m s[mart] | f[ast] | i[mmediate] ] [-o options]

pg_ctl reload [-s] [-D datadir]

pg_ctl status [-D datadir]

pg_ctl promote [-s] [-D datadir]

pg_ctl kill signal_name process_id

pg_ctl register [-N servicename] [-U username] [-P password] [-D datadir] [-S a[uto]|d[emand] ] [-w] [-t seconds] [-s] [-o options]

pg_ctl unregister [-N servicename]
```

Description

pg_ctl is a utility for initializing a PostgreSQL database cluster, starting, stopping, or restarting the PostgreSQL database server (postgres), or displaying the status of a running server. Although the server can be started manually, pg_ctl encapsulates tasks such as redirecting log output and properly detaching from the terminal and process group. It also provides convenient options for controlled shutdown.

The init or initdb mode creates a new PostgreSQL database cluster. A database cluster is a collection of databases that are managed by a single server instance. This mode invokes the initdb command. See initdb for details.

In start mode, a new server is launched. The server is started in the background, and its standard input is attached to /dev/null (or nul on Windows). On Unix-like systems, by default, the server's

standard output and standard error are sent to pg_ctl's standard output (not standard error). The standard output of pg_ctl should then be redirected to a file or piped to another process such as a log rotating program like rotatelogs; otherwise `postgres` will write its output to the controlling terminal (from the background) and will not leave the shell's process group. On Windows, by default the server's standard output and standard error are sent to the terminal. These default behaviors can be changed by using `-l` to append the server's output to a log file. Use of either `-l` or output redirection is recommended.

In `stop` mode, the server that is running in the specified data directory is shut down. Three different shutdown methods can be selected with the `-m` option. "Smart" mode (the default) waits for all active clients to disconnect and any online backup to finish. If the server is in hot standby, recovery and streaming replication will be terminated once all clients have disconnected. "Fast" mode does not wait for clients to disconnect and will terminate an online backup in progress. All active transactions are rolled back and clients are forcibly disconnected, then the server is shut down. "Immediate" mode will abort all server processes immediately, without a clean shutdown. This will lead to a crash-recovery run on the next restart.

`restart` mode effectively executes a stop followed by a start. This allows changing the `postgres` command-line options. `restart` might fail if relative paths specified were specified on the command-line during server start.

`reload` mode simply sends the `postgres` process a SIGHUP signal, causing it to reread its configuration files (`postgresql.conf`, `pg_hba.conf`, etc.). This allows changing of configuration-file options that do not require a complete restart to take effect.

`status` mode checks whether a server is running in the specified data directory. If it is, the PID and the command line options that were used to invoke it are displayed. If the server is not running, the process returns an exit status of 3. If an accessible data directory is not specified, the process returns an exit status of 4.

In `promote` mode, the standby server that is running in the specified data directory is commanded to exit recovery and begin read-write operations.

`kill` mode allows you to send a signal to a specified process. This is particularly valuable for Microsoft Windows which does not have a kill command. Use `--help` to see a list of supported signal names.

`register` mode allows you to register a system service on Microsoft Windows. The `-S` option allows selection of service start type, either "auto" (start service automatically on system startup) or "demand" (start service on demand).

`unregister` mode allows you to unregister a system service on Microsoft Windows. This undoes the effects of the `register` command.

Options

`-c`
`--core-file`

> Attempt to allow server crashes to produce core files, on platforms where this is possible, by lifting any soft resource limit placed on core files. This is useful in debugging or diagnosing problems by allowing a stack trace to be obtained from a failed server process.

`-D` *`datadir`*
`--pgdata` *`datadir`*

Specifies the file system location of the database configuration files. If this is omitted, the environment variable `PGDATA` is used.

`-l` *`filename`*
`--log` *`filename`*

Append the server log output to *`filename`*. If the file does not exist, it is created. The umask is set to 077, so access to the log file is disallowed to other users by default.

`-m` *`mode`*
`--mode` *`mode`*

Specifies the shutdown mode. *`mode`* can be `smart`, `fast`, or `immediate`, or the first letter of one of these three. If this is omitted, `smart` is used.

`-o` *`options`*

Specifies options to be passed directly to the `postgres` command.

The options should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-o` *`initdb-options`*

Specifies options to be passed directly to the `initdb` command.

The options should usually be surrounded by single or double quotes to ensure that they are passed through as a group.

`-p` *`path`*

Specifies the location of the `postgres` executable. By default the `postgres` executable is taken from the same directory as `pg_ctl`, or failing that, the hard-wired installation directory. It is not necessary to use this option unless you are doing something unusual and get errors that the `postgres` executable was not found.

In `init` mode, this option analogously specifies the location of the `initdb` executable.

`-s`
`--silent`

Print only errors, no informational messages.

`-t`
`--timeout`

The maximum number of seconds to wait when waiting for startup or shutdown to complete. The default is 60 seconds.

`-V`
`--version`

Print the pg_ctl version and exit.

`-w`

Wait for the startup or shutdown to complete. Waiting is the default option for shutdowns, but not startups. When waiting for startup, `pg_ctl` repeatedly attempts to connect to the server. When waiting for shutdown, `pg_ctl` waits for the server to remove its PID file. This option allows the entry of an SSL passphrase on startup. `pg_ctl` returns an exit code based on the success of the startup or shutdown.

`-W`

Do not wait for startup or shutdown to complete. This is the default for start and restart modes.

`-?`
`--help`

Show help about pg_ctl command line arguments, and exit.

Options for Windows

`-N` *servicename*

Name of the system service to register. The name will be used as both the service name and the display name.

`-P` *password*

Password for the user to start the service.

`-S` *start-type*

Start type of the system service to register. start-type can be `auto`, or `demand`, or the first letter of one of these two. If this is omitted, `auto` is used.

`-U` *username*

User name for the user to start the service. For domain users, use the format `DOMAIN\username`.

Environment

`PGDATA`

Default data directory location.

`pg_ctl`, like most other PostgreSQL utilities, also uses the environment variables supported by libpq (see Section 31.14). For additional server variables, see postgres.

Files

`postmaster.pid`

The existence of this file in the data directory is used to help pg_ctl determine if the server is currently running.

`postmaster.opts`

If this file exists in the data directory, pg_ctl (in `restart` mode) will pass the contents of the file as options to postgres, unless overridden by the `-o` option. The contents of this file are also displayed in `status` mode.

Examples

Starting the Server

To start the server:

```
$ pg_ctl start
```

To start the server, waiting until the server is accepting connections:

```
$ pg_ctl -w start
```

To start the server using port 5433, and running without `fsync`, use:

```
$ pg_ctl -o "-F -p 5433" start
```

Stopping the Server

To stop the server, use:

```
$ pg_ctl stop
```

The `-m` option allows control over *how* the server shuts down:

```
$ pg_ctl stop -m fast
```

Restarting the Server

Restarting the server is almost equivalent to stopping the server and starting it again, except that `pg_ctl` saves and reuses the command line options that were passed to the previously running instance. To restart the server in the simplest form, use:

```
$ pg_ctl restart
```

To restart the server, waiting for it to shut down and restart:

```
$ pg_ctl -w restart
```

To restart using port 5433, disabling `fsync` upon restart:

```
$ pg_ctl -o "-F -p 5433" restart
```

Showing the Server Status

Here is sample status output from pg_ctl:

```
$ pg_ctl status
pg_ctl: server is running (PID: 13718)
/usr/local/pgsql/bin/postgres "-D" "/usr/local/pgsql/data" "-p" "5433" "-B" "128"
```

This is the command line that would be invoked in restart mode.

See Also

initdb, postgres

pg_resetxlog

Name

pg_resetxlog — reset the write-ahead log and other control information of a PostgreSQL database cluster

Synopsis

pg_resetxlog [-f] [-n] [-o *oid*] [-x *xid*] [-e *xid_epoch*] [-m *mxid*,*mxid*] [-O *mxoff*] [-l *xlogfile*] *datadir*

Description

pg_resetxlog clears the write-ahead log (WAL) and optionally resets some other control information stored in the pg_control file. This function is sometimes needed if these files have become corrupted. It should be used only as a last resort, when the server will not start due to such corruption.

After running this command, it should be possible to start the server, but bear in mind that the database might contain inconsistent data due to partially-committed transactions. You should immediately dump your data, run initdb, and reload. After reload, check for inconsistencies and repair as needed.

This utility can only be run by the user who installed the server, because it requires read/write access to the data directory. For safety reasons, you must specify the data directory on the command line. pg_resetxlog does not use the environment variable PGDATA.

If pg_resetxlog complains that it cannot determine valid data for pg_control, you can force it to proceed anyway by specifying the -f (force) option. In this case plausible values will be substituted for the missing data. Most of the fields can be expected to match, but manual assistance might be needed for the next OID, next transaction ID and epoch, next multitransaction ID and offset, and WAL starting address fields. These fields can be set using the options discussed below. If you are not able to determine correct values for all these fields, -f can still be used, but the recovered database must be treated with even more suspicion than usual: an immediate dump and reload is imperative. *Do not* execute any data-modifying operations in the database before you dump, as any such action is likely to make the corruption worse.

The -o, -x, -e, -m, -O, and -l options allow the next OID, next transaction ID, next transaction ID's epoch, next and oldest multitransaction ID, next multitransaction offset, and WAL starting address values to be set manually. These are only needed when pg_resetxlog is unable to determine appropriate values by reading pg_control. Safe values can be determined as follows:

- A safe value for the next transaction ID (-x) can be determined by looking for the numerically largest file name in the directory pg_clog under the data directory, adding one, and then multiplying by 1048576. Note that the file names are in hexadecimal. It is usually easiest to specify the option value in hexadecimal too. For example, if 0011 is the largest entry in pg_clog, -x 0x1200000 will work (five trailing zeroes provide the proper multiplier).
- A safe value for the next multitransaction ID (first part of -m) can be determined by looking for the numerically largest file name in the directory pg_multixact/offsets under the data directory, adding one, and then multiplying by 65536. Conversely, a safe value for the oldest multitransaction ID (second part of -m) can be determined by looking for the numerically smallest file name in

the same directory and multiplying by 65536. As above, the file names are in hexadecimal, so the easiest way to do this is to specify the option value in hexadecimal and append four zeroes.

- A safe value for the next multitransaction offset (`-O`) can be determined by looking for the numerically largest file name in the directory `pg_multixact/members` under the data directory, adding one, and then multiplying by 52352. As above, the file names are in hexadecimal. There is no simple recipe such as the ones above of appending zeroes.
- The WAL starting address (`-l`) should be larger than any WAL segment file name currently existing in the directory `pg_xlog` under the data directory. These names are also in hexadecimal and have three parts. The first part is the "timeline ID" and should usually be kept the same. For example, if `000000010000000320000004A` is the largest entry in `pg_xlog`, use `-l 000000010000000320000004B` or higher.

  > **Note:** `pg_resetxlog` itself looks at the files in `pg_xlog` and chooses a default `-l` setting beyond the last existing file name. Therefore, manual adjustment of `-l` should only be needed if you are aware of WAL segment files that are not currently present in `pg_xlog`, such as entries in an offline archive; or if the contents of `pg_xlog` have been lost entirely.

- There is no comparably easy way to determine a next OID that's beyond the largest one in the database, but fortunately it is not critical to get the next-OID setting right.
- The transaction ID epoch is not actually stored anywhere in the database except in the field that is set by `pg_resetxlog`, so any value will work so far as the database itself is concerned. You might need to adjust this value to ensure that replication systems such as Slony-I work correctly — if so, an appropriate value should be obtainable from the state of the downstream replicated database.

The `-n` (no operation) option instructs `pg_resetxlog` to print the values reconstructed from `pg_control` and values about to be changed, and then exit without modifying anything. This is mainly a debugging tool, but can be useful as a sanity check before allowing `pg_resetxlog` to proceed for real.

The `-V` and `--version` options print the pg_resetxlog version and exit. The options `-?` and `--help` show supported arguments, and exit.

Notes

This command must not be used when the server is running. `pg_resetxlog` will refuse to start up if it finds a server lock file in the data directory. If the server crashed then a lock file might have been left behind; in that case you can remove the lock file to allow `pg_resetxlog` to run. But before you do so, make doubly certain that there is no server process still alive.

postgres

Name

postgres — PostgreSQL database server

Synopsis

postgres [*option*...]

Description

postgres is the PostgreSQL database server. In order for a client application to access a database it connects (over a network or locally) to a running postgres instance. The postgres instance then starts a separate server process to handle the connection.

One postgres instance always manages the data of exactly one database cluster. A database cluster is a collection of databases that is stored at a common file system location (the "data area"). More than one postgres instance can run on a system at one time, so long as they use different data areas and different communication ports (see below). When postgres starts it needs to know the location of the data area. The location must be specified by the -D option or the PGDATA environment variable; there is no default. Typically, -D or PGDATA points directly to the data area directory created by initdb. Other possible file layouts are discussed in Section 18.2.

By default postgres starts in the foreground and prints log messages to the standard error stream. In practical applications postgres should be started as a background process, perhaps at boot time.

The postgres command can also be called in single-user mode. The primary use for this mode is during bootstrapping by initdb. Sometimes it is used for debugging or disaster recovery; note that running a single-user server is not truly suitable for debugging the server, since no realistic interprocess communication and locking will happen. When invoked in single-user mode from the shell, the user can enter queries and the results will be printed to the screen, but in a form that is more useful for developers than end users. In the single-user mode, the session user will be set to the user with ID 1, and implicit superuser powers are granted to this user. This user does not actually have to exist, so the single-user mode can be used to manually recover from certain kinds of accidental damage to the system catalogs.

Options

postgres accepts the following command-line arguments. For a detailed discussion of the options consult Chapter 18. You can save typing most of these options by setting up a configuration file. Some (safe) options can also be set from the connecting client in an application-dependent way to apply only for that session. For example, if the environment variable PGOPTIONS is set, then libpq-based clients will pass that string to the server, which will interpret it as postgres command-line options.

General Purpose

`-A 0|1`

Enables run-time assertion checks, which is a debugging aid to detect programming mistakes. This option is only available if assertions were enabled when PostgreSQL was compiled. If so, the default is on.

`-B` *nbuffers*

Sets the number of shared buffers for use by the server processes. The default value of this parameter is chosen automatically by initdb. Specifying this option is equivalent to setting the shared_buffers configuration parameter.

`-c` *name=value*

Sets a named run-time parameter. The configuration parameters supported by PostgreSQL are described in Chapter 18. Most of the other command line options are in fact short forms of such a parameter assignment. `-c` can appear multiple times to set multiple parameters.

`-C` *name*

Prints the value of the named run-time parameter, and exits. (See the `-c` option above for details.) This can be used on a running server, and returns values from `postgresql.conf`, modified by any parameters supplied in this invocation. It does not reflect parameters supplied when the cluster was started.

This option is meant for other programs that interact with a server instance, such as pg_ctl, to query configuration parameter values. User-facing applications should instead use SHOW or the `pg_settings` view.

`-d` *debug-level*

Sets the debug level. The higher this value is set, the more debugging output is written to the server log. Values are from 1 to 5. It is also possible to pass `-d 0` for a specific session, which will prevent the server log level of the parent `postgres` process from being propagated to this session.

`-D` *datadir*

Specifies the file system location of the database configuration files. See Section 18.2 for details.

`-e`

Sets the default date style to "European", that is `DMY` ordering of input date fields. This also causes the day to be printed before the month in certain date output formats. See Section 8.5 for more information.

`-F`

Disables `fsync` calls for improved performance, at the risk of data corruption in the event of a system crash. Specifying this option is equivalent to disabling the fsync configuration parameter. Read the detailed documentation before using this!

`-h` *hostname*

Specifies the IP host name or address on which `postgres` is to listen for TCP/IP connections from client applications. The value can also be a comma-separated list of addresses, or `*` to specify listening on all available interfaces. An empty value specifies not listening on any IP addresses, in which case only Unix-domain sockets can be used to connect to the server. Defaults to listening only on localhost. Specifying this option is equivalent to setting the listen_addresses configuration parameter.

`-i`

Allows remote clients to connect via TCP/IP (Internet domain) connections. Without this option, only local connections are accepted. This option is equivalent to setting `listen_addresses` to `*` in `postgresql.conf` or via `-h`.

This option is deprecated since it does not allow access to the full functionality of listen_addresses. It's usually better to set `listen_addresses` directly.

`-k` *directory*

Specifies the directory of the Unix-domain socket on which `postgres` is to listen for connections from client applications. The value can also be a comma-separated list of directories. An empty value specifies not listening on any Unix-domain sockets, in which case only TCP/IP sockets can be used to connect to the server. The default value is normally `/tmp`, but that can be changed at build time. Specifying this option is equivalent to setting the unix_socket_directories configuration parameter.

`-l`

Enables secure connections using SSL. PostgreSQL must have been compiled with support for SSL for this option to be available. For more information on using SSL, refer to Section 17.9.

`-N` *max-connections*

Sets the maximum number of client connections that this server will accept. The default value of this parameter is chosen automatically by initdb. Specifying this option is equivalent to setting the max_connections configuration parameter.

`-o` *extra-options*

The command-line-style options specified in *extra-options* are passed to all server processes started by this `postgres` process. If the option string contains any spaces, the entire string must be quoted.

The use of this option is obsolete; all command-line options for server processes can be specified directly on the `postgres` command line.

`-p` *port*

Specifies the TCP/IP port or local Unix domain socket file extension on which `postgres` is to listen for connections from client applications. Defaults to the value of the `PGPORT` environment variable, or if `PGPORT` is not set, then defaults to the value established during compilation (normally 5432). If you specify a port other than the default port, then all client applications must specify the same port using either command-line options or `PGPORT`.

`-s`

Print time information and other statistics at the end of each command. This is useful for benchmarking or for use in tuning the number of buffers.

`-S` *work-mem*

Specifies the amount of memory to be used by internal sorts and hashes before resorting to temporary disk files. See the description of the `work_mem` configuration parameter in Section 18.4.1.

`-V`
`--version`

Print the postgres version and exit.

`--*name*=*value*`

Sets a named run-time parameter; a shorter form of `-c`.

`--describe-config`

This option dumps out the server's internal configuration variables, descriptions, and defaults in tab-delimited `COPY` format. It is designed primarily for use by administration tools.

`-?`
`--help`

Show help about postgres command line arguments, and exit.

Semi-internal Options

The options described here are used mainly for debugging purposes, and in some cases to assist with recovery of severely damaged databases. There should be no reason to use them in a production database setup. They are listed here only for use by PostgreSQL system developers. Furthermore, these options might change or be removed in a future release without notice.

`-f { s | i | o | b | t | n | m | h }`

Forbids the use of particular scan and join methods: `s` and `i` disable sequential and index scans respectively, `o`, `b` and `t` disable index-only scans, bitmap index scans, and TID scans respectively, while `n`, `m`, and `h` disable nested-loop, merge and hash joins respectively.

Neither sequential scans nor nested-loop joins can be disabled completely; the `-fs` and `-fn` options simply discourage the optimizer from using those plan types if it has any other alternative.

`-n`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `postgres` will not reinitialize shared data structures. A knowledgeable system programmer can then use a debugger to examine shared memory and semaphore state.

`-O`

Allows the structure of system tables to be modified. This is used by `initdb`.

`-P`

Ignore system indexes when reading system tables, but still update the indexes when modifying the tables. This is useful when recovering from damaged system indexes.

`-t pa[rser] | pl[anner] | e[xecutor]`

Print timing statistics for each query relating to each of the major system modules. This option cannot be used together with the `-s` option.

`-T`

This option is for debugging problems that cause a server process to die abnormally. The ordinary strategy in this situation is to notify all other server processes that they must terminate and then reinitialize the shared memory and semaphores. This is because an errant server process could have corrupted some shared state before terminating. This option specifies that `postgres` will stop all other server processes by sending the signal `SIGSTOP`, but will not cause them to terminate. This permits system programmers to collect core dumps from all server processes by hand.

`-v` *protocol*

Specifies the version number of the frontend/backend protocol to be used for a particular session. This option is for internal use only.

`-W` *seconds*

A delay of this many seconds occurs when a new server process is started, after it conducts the authentication procedure. This is intended to give an opportunity to attach to the server process with a debugger.

Options for Single-User Mode

The following options only apply to the single-user mode.

`--single`

Selects the single-user mode. This must be the first argument on the command line.

database

Specifies the name of the database to be accessed. This must be the last argument on the command line. If it is omitted it defaults to the user name.

`-E`

Echo all commands.

`-j`

Disables use of newline as a statement delimiter.

`-r` *filename*

Send all server log output to *filename*. This option is only honored when supplied as a command-line option.

Environment

`PGCLIENTENCODING`

Default character encoding used by clients. (The clients can override this individually.) This value can also be set in the configuration file.

`PGDATA`

Default data directory location

`PGDATESTYLE`

Default value of the DateStyle run-time parameter. (The use of this environment variable is deprecated.)

`PGPORT`

Default port number (preferably set in the configuration file)

`TZ`

Server time zone

Diagnostics

A failure message mentioning `semget` or `shmget` probably indicates you need to configure your kernel to provide adequate shared memory and semaphores. For more discussion see Section 17.4. You might be able to postpone reconfiguring your kernel by decreasing shared_buffers to reduce the shared memory consumption of PostgreSQL, and/or by reducing max_connections to reduce the semaphore consumption.

A failure message suggesting that another server is already running should be checked carefully, for example by using the command

```
$ ps ax | grep postgres
```

or

```
$ ps -ef | grep postgres
```

depending on your system. If you are certain that no conflicting server is running, you can remove the lock file mentioned in the message and try again.

A failure message indicating inability to bind to a port might indicate that that port is already in use by some non-PostgreSQL process. You might also get this error if you terminate `postgres` and immediately restart it using the same port; in this case, you must simply wait a few seconds until the operating system closes the port before trying again. Finally, you might get this error if you specify a port number that your operating system considers to be reserved. For example, many versions of Unix consider port numbers under 1024 to be "trusted" and only permit the Unix superuser to access them.

Notes

The utility command pg_ctl can be used to start and shut down the `postgres` server safely and comfortably.

If at all possible, *do not* use `SIGKILL` to kill the main `postgres` server. Doing so will prevent `postgres` from freeing the system resources (e.g., shared memory and semaphores) that it holds before terminating. This might cause problems for starting a fresh `postgres` run.

To terminate the `postgres` server normally, the signals `SIGTERM`, `SIGINT`, or `SIGQUIT` can be used. The first will wait for all clients to terminate before quitting, the second will forcefully disconnect all clients, and the third will quit immediately without proper shutdown, resulting in a recovery run during restart.

The `SIGHUP` signal will reload the server configuration files. It is also possible to send `SIGHUP` to an individual server process, but that is usually not sensible.

To cancel a running query, send the `SIGINT` signal to the process running that command. To terminate a backend process cleanly, send `SIGTERM` to that process. See also `pg_cancel_backend` and `pg_terminate_backend` in Section 9.26.2 for the SQL-callable equivalents of these two actions.

The `postgres` server uses `SIGQUIT` to tell subordinate server processes to terminate without normal cleanup. This signal *should not* be used by users. It is also unwise to send `SIGKILL` to a server process — the main `postgres` process will interpret this as a crash and will force all the sibling processes to quit as part of its standard crash-recovery procedure.

Bugs

The `--` options will not work on FreeBSD or OpenBSD. Use `-c` instead. This is a bug in the affected operating systems; a future release of PostgreSQL will provide a workaround if this is not fixed.

Usage

To start a single-user mode server, use a command like

```
postgres --single -D /usr/local/pgsql/data other-options my_database
```

Provide the correct path to the database directory with `-D`, or make sure that the environment variable `PGDATA` is set. Also specify the name of the particular database you want to work in.

Normally, the single-user mode server treats newline as the command entry terminator; there is no intelligence about semicolons, as there is in psql. To continue a command across multiple lines, you must type backslash just before each newline except the last one.

But if you use the `-j` command line switch, then newline does not terminate command entry. In this case, the server will read the standard input until the end-of-file (EOF) marker, then process the input as a single command string. Backslash-newline is not treated specially in this case.

To quit the session, type EOF (**Control+D**, usually). If you've used `-j`, two consecutive EOFs are needed to exit.

Note that the single-user mode server does not provide sophisticated line-editing features (no command history, for example). Single-User mode also does not do any background processing, like automatic checkpoints.

Examples

To start `postgres` in the background using default values, type:

```
$ nohup postgres >logfile 2>&1 </dev/null &
```

To start `postgres` with a specific port, e.g. 1234:

```
$ postgres -p 1234
```

To connect to this server using psql, specify this port with the -p option:

```
$ psql -p 1234
```

or set the environment variable `PGPORT`:

```
$ export PGPORT=1234
$ psql
```

Named run-time parameters can be set in either of these styles:

```
$ postgres -c work_mem=1234
$ postgres --work-mem=1234
```

Either form overrides whatever setting might exist for `work_mem` in `postgresql.conf`. Notice that underscores in parameter names can be written as either underscore or dash on the command line. Except for short-term experiments, it's probably better practice to edit the setting in `postgresql.conf` than to rely on a command-line switch to set a parameter.

See Also

initdb, pg_ctl

postmaster

Name

`postmaster` — PostgreSQL database server

Synopsis

`postmaster` [*`option`*...]

Description

`postmaster` is a deprecated alias of `postgres`.

See Also

postgres

VII. Internals

This part contains assorted information that might be of use to PostgreSQL developers.

Chapter 47. Overview of PostgreSQL Internals

Author: This chapter originated as part of *Enhancement of the ANSI SQL Implementation of PostgreSQL*, Stefan Simkovics' Master's Thesis prepared at Vienna University of Technology under the direction of O.Univ.Prof.Dr. Georg Gottlob and Univ.Ass. Mag. Katrin Seyr.

This chapter gives an overview of the internal structure of the backend of PostgreSQL. After having read the following sections you should have an idea of how a query is processed. This chapter does not aim to provide a detailed description of the internal operation of PostgreSQL, as such a document would be very extensive. Rather, this chapter is intended to help the reader understand the general sequence of operations that occur within the backend from the point at which a query is received, to the point at which the results are returned to the client.

47.1. The Path of a Query

Here we give a short overview of the stages a query has to pass in order to obtain a result.

1. A connection from an application program to the PostgreSQL server has to be established. The application program transmits a query to the server and waits to receive the results sent back by the server.
2. The *parser stage* checks the query transmitted by the application program for correct syntax and creates a *query tree*.
3. The *rewrite system* takes the query tree created by the parser stage and looks for any *rules* (stored in the *system catalogs*) to apply to the query tree. It performs the transformations given in the *rule bodies*.

   One application of the rewrite system is in the realization of *views*. Whenever a query against a view (i.e., a *virtual table*) is made, the rewrite system rewrites the user's query to a query that accesses the *base tables* given in the *view definition* instead.
4. The *planner/optimizer* takes the (rewritten) query tree and creates a *query plan* that will be the input to the *executor*.

   It does so by first creating all possible *paths* leading to the same result. For example if there is an index on a relation to be scanned, there are two paths for the scan. One possibility is a simple sequential scan and the other possibility is to use the index. Next the cost for the execution of each path is estimated and the cheapest path is chosen. The cheapest path is expanded into a complete plan that the executor can use.
5. The executor recursively steps through the *plan tree* and retrieves rows in the way represented by the plan. The executor makes use of the *storage system* while scanning relations, performs *sorts* and *joins*, evaluates *qualifications* and finally hands back the rows derived.

In the following sections we will cover each of the above listed items in more detail to give a better understanding of PostgreSQL's internal control and data structures.

47.2. How Connections are Established

PostgreSQL is implemented using a simple "process per user" client/server model. In this model there is one *client process* connected to exactly one *server process*. As we do not know ahead of time how many connections will be made, we have to use a *master process* that spawns a new server process every time a connection is requested. This master process is called `postgres` and listens at a specified TCP/IP port for incoming connections. Whenever a request for a connection is detected the `postgres` process spawns a new server process. The server tasks communicate with each other using *semaphores* and *shared memory* to ensure data integrity throughout concurrent data access.

The client process can be any program that understands the PostgreSQL protocol described in Chapter 49. Many clients are based on the C-language library libpq, but several independent implementations of the protocol exist, such as the Java JDBC driver.

Once a connection is established the client process can send a query to the *backend* (server). The query is transmitted using plain text, i.e., there is no parsing done in the *frontend* (client). The server parses the query, creates an *execution plan*, executes the plan and returns the retrieved rows to the client by transmitting them over the established connection.

47.3. The Parser Stage

The *parser stage* consists of two parts:

- The *parser* defined in `gram.y` and `scan.l` is built using the Unix tools bison and flex.
- The *transformation process* does modifications and augmentations to the data structures returned by the parser.

47.3.1. Parser

The parser has to check the query string (which arrives as plain text) for valid syntax. If the syntax is correct a *parse tree* is built up and handed back; otherwise an error is returned. The parser and lexer are implemented using the well-known Unix tools bison and flex.

The *lexer* is defined in the file `scan.l` and is responsible for recognizing *identifiers*, the *SQL key words* etc. For every key word or identifier that is found, a *token* is generated and handed to the parser.

The parser is defined in the file `gram.y` and consists of a set of *grammar rules* and *actions* that are executed whenever a rule is fired. The code of the actions (which is actually C code) is used to build up the parse tree.

The file `scan.l` is transformed to the C source file `scan.c` using the program flex and `gram.y` is transformed to `gram.c` using bison. After these transformations have taken place a normal C compiler can be used to create the parser. Never make any changes to the generated C files as they will be overwritten the next time flex or bison is called.

> **Note:** The mentioned transformations and compilations are normally done automatically using the *makefiles* shipped with the PostgreSQL source distribution.

A detailed description of bison or the grammar rules given in `gram.y` would be beyond the scope of this paper. There are many books and documents dealing with flex and bison. You should be familiar with bison before you start to study the grammar given in `gram.y` otherwise you won't understand what happens there.

47.3.2. Transformation Process

The parser stage creates a parse tree using only fixed rules about the syntactic structure of SQL. It does not make any lookups in the system catalogs, so there is no possibility to understand the detailed semantics of the requested operations. After the parser completes, the *transformation process* takes the tree handed back by the parser as input and does the semantic interpretation needed to understand which tables, functions, and operators are referenced by the query. The data structure that is built to represent this information is called the *query tree*.

The reason for separating raw parsing from semantic analysis is that system catalog lookups can only be done within a transaction, and we do not wish to start a transaction immediately upon receiving a query string. The raw parsing stage is sufficient to identify the transaction control commands (`BEGIN`, `ROLLBACK`, etc), and these can then be correctly executed without any further analysis. Once we know that we are dealing with an actual query (such as `SELECT` or `UPDATE`), it is okay to start a transaction if we're not already in one. Only then can the transformation process be invoked.

The query tree created by the transformation process is structurally similar to the raw parse tree in most places, but it has many differences in detail. For example, a `FuncCall` node in the parse tree represents something that looks syntactically like a function call. This might be transformed to either a `FuncExpr` or `Aggref` node depending on whether the referenced name turns out to be an ordinary function or an aggregate function. Also, information about the actual data types of columns and expression results is added to the query tree.

47.4. The PostgreSQL Rule System

PostgreSQL supports a powerful *rule system* for the specification of *views* and ambiguous *view updates*. Originally the PostgreSQL rule system consisted of two implementations:

- The first one worked using *row level* processing and was implemented deep in the *executor*. The rule system was called whenever an individual row had been accessed. This implementation was removed in 1995 when the last official release of the Berkeley Postgres project was transformed into Postgres95.
- The second implementation of the rule system is a technique called *query rewriting*. The *rewrite system* is a module that exists between the *parser stage* and the *planner/optimizer*. This technique is still implemented.

The query rewriter is discussed in some detail in Chapter 38, so there is no need to cover it here. We will only point out that both the input and the output of the rewriter are query trees, that is, there is no change in the representation or level of semantic detail in the trees. Rewriting can be thought of as a form of macro expansion.

47.5. Planner/Optimizer

The task of the *planner/optimizer* is to create an optimal execution plan. A given SQL query (and hence, a query tree) can be actually executed in a wide variety of different ways, each of which will produce the same set of results. If it is computationally feasible, the query optimizer will examine each of these possible execution plans, ultimately selecting the execution plan that is expected to run the fastest.

> **Note:** In some situations, examining each possible way in which a query can be executed would take an excessive amount of time and memory space. In particular, this occurs when executing queries involving large numbers of join operations. In order to determine a reasonable (not necessarily optimal) query plan in a reasonable amount of time, PostgreSQL uses a *Genetic Query Optimizer* (see Chapter 54) when the number of joins exceeds a threshold (see geqo_threshold).

The planner's search procedure actually works with data structures called *paths*, which are simply cut-down representations of plans containing only as much information as the planner needs to make its decisions. After the cheapest path is determined, a full-fledged *plan tree* is built to pass to the executor. This represents the desired execution plan in sufficient detail for the executor to run it. In the rest of this section we'll ignore the distinction between paths and plans.

47.5.1. Generating Possible Plans

The planner/optimizer starts by generating plans for scanning each individual relation (table) used in the query. The possible plans are determined by the available indexes on each relation. There is always the possibility of performing a sequential scan on a relation, so a sequential scan plan is always created. Assume an index is defined on a relation (for example a B-tree index) and a query contains the restriction `relation.attribute OPR constant`. If `relation.attribute` happens to match the key of the B-tree index and `OPR` is one of the operators listed in the index's *operator class*, another plan is created using the B-tree index to scan the relation. If there are further indexes present and the restrictions in the query happen to match a key of an index, further plans will be considered. Index scan plans are also generated for indexes that have a sort ordering that can match the query's `ORDER BY` clause (if any), or a sort ordering that might be useful for merge joining (see below).

If the query requires joining two or more relations, plans for joining relations are considered after all feasible plans have been found for scanning single relations. The three available join strategies are:

- *nested loop join*: The right relation is scanned once for every row found in the left relation. This strategy is easy to implement but can be very time consuming. (However, if the right relation can be scanned with an index scan, this can be a good strategy. It is possible to use values from the current row of the left relation as keys for the index scan of the right.)
- *merge join*: Each relation is sorted on the join attributes before the join starts. Then the two relations are scanned in parallel, and matching rows are combined to form join rows. This kind of join is more attractive because each relation has to be scanned only once. The required sorting might be achieved either by an explicit sort step, or by scanning the relation in the proper order using an index on the join key.
- *hash join*: the right relation is first scanned and loaded into a hash table, using its join attributes as hash keys. Next the left relation is scanned and the appropriate values of every row found are used as hash keys to locate the matching rows in the table.

When the query involves more than two relations, the final result must be built up by a tree of join steps, each with two inputs. The planner examines different possible join sequences to find the cheapest one.

If the query uses fewer than geqo_threshold relations, a near-exhaustive search is conducted to find the best join sequence. The planner preferentially considers joins between any two relations for which there exist a corresponding join clause in the `WHERE` qualification (i.e., for which a restriction like `where rel1.attr1=rel2.attr2` exists). Join pairs with no join clause are considered only when there is no other choice, that is, a particular relation has no available join clauses to any other relation. All possible plans are generated for every join pair considered by the planner, and the one that is (estimated to be) the cheapest is chosen.

When `geqo_threshold` is exceeded, the join sequences considered are determined by heuristics, as described in Chapter 54. Otherwise the process is the same.

The finished plan tree consists of sequential or index scans of the base relations, plus nested-loop, merge, or hash join nodes as needed, plus any auxiliary steps needed, such as sort nodes or aggregate-function calculation nodes. Most of these plan node types have the additional ability to do *selection* (discarding rows that do not meet a specified Boolean condition) and *projection* (computation of a derived column set based on given column values, that is, evaluation of scalar expressions where needed). One of the responsibilities of the planner is to attach selection conditions from the `WHERE` clause and computation of required output expressions to the most appropriate nodes of the plan tree.

47.6. Executor

The *executor* takes the plan created by the planner/optimizer and recursively processes it to extract the required set of rows. This is essentially a demand-pull pipeline mechanism. Each time a plan node is called, it must deliver one more row, or report that it is done delivering rows.

To provide a concrete example, assume that the top node is a `MergeJoin` node. Before any merge can be done two rows have to be fetched (one from each subplan). So the executor recursively calls itself to process the subplans (it starts with the subplan attached to `lefttree`). The new top node (the top node of the left subplan) is, let's say, a `Sort` node and again recursion is needed to obtain an input row. The child node of the `Sort` might be a `SeqScan` node, representing actual reading of a table. Execution of this node causes the executor to fetch a row from the table and return it up to the calling node. The `Sort` node will repeatedly call its child to obtain all the rows to be sorted. When the input is exhausted (as indicated by the child node returning a NULL instead of a row), the `Sort` code performs the sort, and finally is able to return its first output row, namely the first one in sorted order. It keeps the remaining rows stored so that it can deliver them in sorted order in response to later demands.

The `MergeJoin` node similarly demands the first row from its right subplan. Then it compares the two rows to see if they can be joined; if so, it returns a join row to its caller. On the next call, or immediately if it cannot join the current pair of inputs, it advances to the next row of one table or the other (depending on how the comparison came out), and again checks for a match. Eventually, one subplan or the other is exhausted, and the `MergeJoin` node returns NULL to indicate that no more join rows can be formed.

Complex queries can involve many levels of plan nodes, but the general approach is the same: each node computes and returns its next output row each time it is called. Each node is also responsible for applying any selection or projection expressions that were assigned to it by the planner.

The executor mechanism is used to evaluate all four basic SQL query types: `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. For `SELECT`, the top-level executor code only needs to send each row returned

by the query plan tree off to the client. For `INSERT`, each returned row is inserted into the target table specified for the `INSERT`. This is done in a special top-level plan node called `ModifyTable`. (A simple `INSERT ... VALUES` command creates a trivial plan tree consisting of a single `Result` node, which computes just one result row, and `ModifyTable` above it to perform the insertion. But `INSERT ... SELECT` can demand the full power of the executor mechanism.) For `UPDATE`, the planner arranges that each computed row includes all the updated column values, plus the *TID* (tuple ID, or row ID) of the original target row; this data is fed into a `ModifyTable` node, which uses the information to create a new updated row and mark the old row deleted. For `DELETE`, the only column that is actually returned by the plan is the TID, and the `ModifyTable` node simply uses the TID to visit each target row and mark it deleted.

Chapter 48. System Catalogs

The system catalogs are the place where a relational database management system stores schema metadata, such as information about tables and columns, and internal bookkeeping information. PostgreSQL's system catalogs are regular tables. You can drop and recreate the tables, add columns, insert and update values, and severely mess up your system that way. Normally, one should not change the system catalogs by hand, there are always SQL commands to do that. (For example, `CREATE DATABASE` inserts a row into the `pg_database` catalog — and actually creates the database on disk.) There are some exceptions for particularly esoteric operations, such as adding index access methods.

48.1. Overview

Table 48-1 lists the system catalogs. More detailed documentation of each catalog follows below.

Most system catalogs are copied from the template database during database creation and are thereafter database-specific. A few catalogs are physically shared across all databases in a cluster; these are noted in the descriptions of the individual catalogs.

Table 48-1. System Catalogs

Catalog Name	Purpose
`pg_aggregate`	aggregate functions
`pg_am`	index access methods
`pg_amop`	access method operators
`pg_amproc`	access method support procedures
`pg_attrdef`	column default values
`pg_attribute`	table columns ("attributes")
`pg_authid`	authorization identifiers (roles)
`pg_auth_members`	authorization identifier membership relationships
`pg_cast`	casts (data type conversions)
`pg_class`	tables, indexes, sequences, views ("relations")
`pg_collation`	collations (locale information)
`pg_constraint`	check constraints, unique constraints, primary key constraints, foreign key constraints
`pg_conversion`	encoding conversion information
`pg_database`	databases within this database cluster
`pg_db_role_setting`	per-role and per-database settings
`pg_default_acl`	default privileges for object types
`pg_depend`	dependencies between database objects
`pg_description`	descriptions or comments on database objects
`pg_enum`	enum label and value definitions
`pg_event_trigger`	event triggers

Catalog Name	Purpose
pg_extension	installed extensions
pg_foreign_data_wrapper	foreign-data wrapper definitions
pg_foreign_server	foreign server definitions
pg_foreign_table	additional foreign table information
pg_index	additional index information
pg_inherits	table inheritance hierarchy
pg_language	languages for writing functions
pg_largeobject	data pages for large objects
pg_largeobject_metadata	metadata for large objects
pg_namespace	schemas
pg_opclass	access method operator classes
pg_operator	operators
pg_opfamily	access method operator families
pg_pltemplate	template data for procedural languages
pg_proc	functions and procedures
pg_range	information about range types
pg_rewrite	query rewrite rules
pg_replication_slots	replication slot information
pg_seclabel	security labels on database objects
pg_shdepend	dependencies on shared objects
pg_shdescription	comments on shared objects
pg_shseclabel	security labels on shared database objects
pg_statistic	planner statistics
pg_tablespace	tablespaces within this database cluster
pg_trigger	triggers
pg_ts_config	text search configurations
pg_ts_config_map	text search configurations' token mappings
pg_ts_dict	text search dictionaries
pg_ts_parser	text search parsers
pg_ts_template	text search templates
pg_type	data types
pg_user_mapping	mappings of users to foreign servers

48.2. pg_aggregate

The catalog pg_aggregate stores information about aggregate functions. An aggregate function is a function that operates on a set of values (typically one column from each row that matches a query condition) and returns a single value computed from all these values. Typical aggregate functions are sum, count, and max. Each entry in pg_aggregate is an extension of an entry in pg_proc. The pg_proc entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

Table 48-2. `pg_aggregate` Columns

Name	Type	References	Description
`aggfnoid`	`regproc`	`pg_proc.oid`	`pg_proc` OID of the aggregate function
`aggkind`	`char`		Aggregate kind: `n` for "normal" aggregates, `o` for "ordered-set" aggregates, or `h` for "hypothetical-set" aggregates
`aggnumdirectargs`	`int2`		Number of direct (non-aggregated) arguments of an ordered-set or hypothetical-set aggregate, counting a variadic array as one argument. If equal to `pronargs`, the aggregate must be variadic and the variadic array describes the aggregated arguments as well as the final direct arguments. Always zero for normal aggregates.
`aggtransfn`	`regproc`	`pg_proc.oid`	Transition function
`aggfinalfn`	`regproc`	`pg_proc.oid`	Final function (zero if none)
`aggmtransfn`	`regproc`	`pg_proc.oid`	Forward transition function for moving-aggregate mode (zero if none)
`aggminvtransfn`	`regproc`	`pg_proc.oid`	Inverse transition function for moving-aggregate mode (zero if none)
`aggmfinalfn`	`regproc`	`pg_proc.oid`	Final function for moving-aggregate mode (zero if none)
`aggfinalextra`	`bool`		True to pass extra dummy arguments to `aggfinalfn`
`aggmfinalextra`	`bool`		True to pass extra dummy arguments to `aggmfinalfn`

Name	Type	References	Description
aggsortop	oid	pg_operator.oid	Associated sort operator (zero if none)
aggtranstype	oid	pg_type.oid	Data type of the aggregate function's internal transition (state) data
aggtransspace	int4		Approximate average size (in bytes) of the transition state data, or zero to use a default estimate
aggmtranstype	oid	pg_type.oid	Data type of the aggregate function's internal transition (state) data for moving-aggregate mode (zero if none)
aggmtransspace	int4		Approximate average size (in bytes) of the transition state data for moving-aggregate mode, or zero to use a default estimate
agginitval	text		The initial value of the transition state. This is a text field containing the initial value in its external string representation. If this field is null, the transition state value starts out null.
aggminitval	text		The initial value of the transition state for moving-aggregate mode. This is a text field containing the initial value in its external string representation. If this field is null, the transition state value starts out null.

New aggregate functions are registered with the CREATE AGGREGATE command. See Section 35.10 for more information about writing aggregate functions and the meaning of the transition functions, etc.

48.3. pg_am

The catalog pg_am stores information about index access methods. There is one row for each index access method supported by the system. The contents of this catalog are discussed in detail in Chapter 55.

Table 48-3. pg_am Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
amname	name		Name of the access method
amstrategies	int2		Number of operator strategies for this access method, or zero if access method does not have a fixed set of operator strategies
amsupport	int2		Number of support routines for this access method
amcanorder	bool		Does the access method support ordered scans sorted by the indexed column's value?
amcanorderbyop	bool		Does the access method support ordered scans sorted by the result of an operator on the indexed column?
amcanbackward	bool		Does the access method support backward scanning?
amcanunique	bool		Does the access method support unique indexes?
amcanmulticol	bool		Does the access method support multicolumn indexes?
amoptionalkey	bool		Does the access method support a scan without any constraint for the first index column?

Name	Type	References	Description
amsearcharray	bool		Does the access method support ScalarArrayOpExpr searches?
amsearchnulls	bool		Does the access method support IS NULL/NOT NULL searches?
amstorage	bool		Can index storage data type differ from column data type?
amclusterable	bool		Can an index of this type be clustered on?
ampredlocks	bool		Does an index of this type manage fine-grained predicate locks?
amkeytype	oid	pg_type.oid	Type of data stored in index, or zero if not a fixed type
aminsert	regproc	pg_proc.oid	"Insert this tuple" function
ambeginscan	regproc	pg_proc.oid	"Prepare for index scan" function
amgettuple	regproc	pg_proc.oid	"Next valid tuple" function, or zero if none
amgetbitmap	regproc	pg_proc.oid	"Fetch all valid tuples" function, or zero if none
amrescan	regproc	pg_proc.oid	"(Re)start index scan" function
amendscan	regproc	pg_proc.oid	"Clean up after index scan" function
ammarkpos	regproc	pg_proc.oid	"Mark current scan position" function
amrestrpos	regproc	pg_proc.oid	"Restore marked scan position" function
ambuild	regproc	pg_proc.oid	"Build new index" function
ambuildempty	regproc	pg_proc.oid	"Build empty index" function
ambulkdelete	regproc	pg_proc.oid	Bulk-delete function
amvacuumcleanup	regproc	pg_proc.oid	Post-VACUUM cleanup function

Name	Type	References	Description
amcanreturn	regproc	pg_proc.oid	Function to check whether index supports index-only scans, or zero if none
amcostestimate	regproc	pg_proc.oid	Function to estimate cost of an index scan
amoptions	regproc	pg_proc.oid	Function to parse and validate reloptions for an index

48.4. pg_amop

The catalog pg_amop stores information about operators associated with access method operator families. There is one row for each operator that is a member of an operator family. A family member can be either a *search* operator or an *ordering* operator. An operator can appear in more than one family, but cannot appear in more than one search position nor more than one ordering position within a family. (It is allowed, though unlikely, for an operator to be used for both search and ordering purposes.)

Table 48-4. pg_amop Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
amopfamily	oid	pg_opfamily.oid	The operator family this entry is for
amoplefttype	oid	pg_type.oid	Left-hand input data type of operator
amoprighttype	oid	pg_type.oid	Right-hand input data type of operator
amopstrategy	int2		Operator strategy number
amoppurpose	char		Operator purpose, either s for search or o for ordering
amopopr	oid	pg_operator.oid	OID of the operator
amopmethod	oid	pg_am.oid	Index access method operator family is for
amopsortfamily	oid	pg_opfamily.oid	The B-tree operator family this entry sorts according to, if an ordering operator; zero if a search operator

A “search” operator entry indicates that an index of this operator family can be searched to find all

rows satisfying WHERE *indexed_column operator constant*. Obviously, such an operator must return boolean, and its left-hand input type must match the index's column data type.

An "ordering" operator entry indicates that an index of this operator family can be scanned to return rows in the order represented by ORDER BY *indexed_column operator constant*. Such an operator could return any sortable data type, though again its left-hand input type must match the index's column data type. The exact semantics of the ORDER BY are specified by the amopsortfamily column, which must reference a B-tree operator family for the operator's result type.

> **Note:** At present, it's assumed that the sort order for an ordering operator is the default for the referenced operator family, i.e., ASC NULLS LAST. This might someday be relaxed by adding additional columns to specify sort options explicitly.

An entry's amopmethod must match the opfmethod of its containing operator family (including amopmethod here is an intentional denormalization of the catalog structure for performance reasons). Also, amoplefttype and amoprighttype must match the oprleft and oprright fields of the referenced pg_operator entry.

48.5. pg_amproc

The catalog pg_amproc stores information about support procedures associated with access method operator families. There is one row for each support procedure belonging to an operator family.

Table 48-5. pg_amproc Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
amprocfamily	oid	pg_opfamily.oid	The operator family this entry is for
amproclefttype	oid	pg_type.oid	Left-hand input data type of associated operator
amprocrighttype	oid	pg_type.oid	Right-hand input data type of associated operator
amprocnum	int2		Support procedure number
amproc	regproc	pg_proc.oid	OID of the procedure

The usual interpretation of the amproclefttype and amprocrighttype fields is that they identify the left and right input types of the operator(s) that a particular support procedure supports. For some access methods these match the input data type(s) of the support procedure itself, for others not. There is a notion of "default" support procedures for an index, which are those with amproclefttype and amprocrighttype both equal to the index operator class's opcintype.

48.6. pg_attrdef

The catalog pg_attrdef stores column default values. The main information about columns is stored in pg_attribute (see below). Only columns that explicitly specify a default value (when the table is created or the column is added) will have an entry here.

Table 48-6. pg_attrdef Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
adrelid	oid	pg_class.oid	The table this column belongs to
adnum	int2	pg_attribute.attnum	The number of the column
adbin	pg_node_tree		The internal representation of the column default value
adsrc	text		A human-readable representation of the default value

The adsrc field is historical, and is best not used, because it does not track outside changes that might affect the representation of the default value. Reverse-compiling the adbin field (with pg_get_expr for example) is a better way to display the default value.

48.7. pg_attribute

The catalog pg_attribute stores information about table columns. There will be exactly one pg_attribute row for every column in every table in the database. (There will also be attribute entries for indexes, and indeed all objects that have pg_class entries.)

The term attribute is equivalent to column and is used for historical reasons.

Table 48-7. pg_attribute Columns

Name	Type	References	Description
attrelid	oid	pg_class.oid	The table this column belongs to
attname	name		The column name
atttypid	oid	pg_type.oid	The data type of this column

Name	Type	References	Description
attstattarget	int4		attstattarget controls the level of detail of statistics accumulated for this column by ANALYZE. A zero value indicates that no statistics should be collected. A negative value says to use the system default statistics target. The exact meaning of positive values is data type-dependent. For scalar data types, attstattarget is both the target number of "most common values" to collect, and the target number of histogram bins to create.
attlen	int2		A copy of pg_type.typlen of this column's type
attnum	int2		The number of the column. Ordinary columns are numbered from 1 up. System columns, such as oid, have (arbitrary) negative numbers.
attndims	int4		Number of dimensions, if the column is an array type; otherwise 0. (Presently, the number of dimensions of an array is not enforced, so any nonzero value effectively means "it's an array".)
attcacheoff	int4		Always -1 in storage, but when loaded into a row descriptor in memory this might be updated to cache the offset of the attribute within the row

Name	Type	References	Description
atttypmod	int4		atttypmod records type-specific data supplied at table creation time (for example, the maximum length of a varchar column). It is passed to type-specific input functions and length coercion functions. The value will generally be -1 for types that do not need atttypmod.
attbyval	bool		A copy of pg_type.typbyval of this column's type
attstorage	char		Normally a copy of pg_type.typstorage of this column's type. For TOAST-able data types, this can be altered after column creation to control storage policy.
attalign	char		A copy of pg_type.typalign of this column's type
attnotnull	bool		This represents a not-null constraint. It is possible to change this column to enable or disable the constraint.
atthasdef	bool		This column has a default value, in which case there will be a corresponding entry in the pg_attrdef catalog that actually defines the value.
attisdropped	bool		This column has been dropped and is no longer valid. A dropped column is still physically present in the table, but is ignored by the parser and so cannot be accessed via SQL.

Name	Type	References	Description
attislocal	bool		This column is defined locally in the relation. Note that a column can be locally defined and inherited simultaneously.
attinhcount	int4		The number of direct ancestors this column has. A column with a nonzero number of ancestors cannot be dropped nor renamed.
attcollation	oid	pg_collation.oid	The defined collation of the column, or zero if the column is not of a collatable data type.
attacl	aclitem[]		Column-level access privileges, if any have been granted specifically on this column
attoptions	text[]		Attribute-level options, as "keyword=value" strings
attfdwoptions	text[]		Attribute-level foreign data wrapper options, as "keyword=value" strings

In a dropped column's pg_attribute entry, atttypid is reset to zero, but attlen and the other fields copied from pg_type are still valid. This arrangement is needed to cope with the situation where the dropped column's data type was later dropped, and so there is no pg_type row anymore. attlen and the other fields can be used to interpret the contents of a row of the table.

48.8. pg_authid

The catalog pg_authid contains information about database authorization identifiers (roles). A role subsumes the concepts of "users" and "groups". A user is essentially just a role with the rolcanlogin flag set. Any role (with or without rolcanlogin) can have other roles as members; see pg_auth_members.

Since this catalog contains passwords, it must not be publicly readable. pg_roles is a publicly readable view on pg_authid that blanks out the password field.

Chapter 20 contains detailed information about user and privilege management.

Because user identities are cluster-wide, pg_authid is shared across all databases of a cluster: there is only one copy of pg_authid per cluster, not one per database.

Table 48-8. `pg_authid` Columns

Name	Type	Description
`oid`	`oid`	Row identifier (hidden attribute; must be explicitly selected)
`rolname`	`name`	Role name
`rolsuper`	`bool`	Role has superuser privileges
`rolinherit`	`bool`	Role automatically inherits privileges of roles it is a member of
`rolcreaterole`	`bool`	Role can create more roles
`rolcreatedb`	`bool`	Role can create databases
`rolcatupdate`	`bool`	Role can update system catalogs directly. (Even a superuser cannot do this unless this column is true)
`rolcanlogin`	`bool`	Role can log in. That is, this role can be given as the initial session authorization identifier
`rolreplication`	`bool`	Role is a replication role. That is, this role can initiate streaming replication (see Section 25.2.5) and set/unset the system backup mode using `pg_start_backup` and `pg_stop_backup`
`rolconnlimit`	`int4`	For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
`rolpassword`	`text`	Password (possibly encrypted); null if none. If the password is encrypted, this column will begin with the string `md5` followed by a 32-character hexadecimal MD5 hash. The MD5 hash will be of the user's password concatenated to their user name. For example, if user `joe` has password `xyzzy`, PostgreSQL will store the md5 hash of `xyzzyjoe`. A password that does not follow that format is assumed to be unencrypted.
`rolvaliduntil`	`timestamptz`	Password expiry time (only used for password authentication); null if no expiration

48.9. pg_auth_members

The catalog pg_auth_members shows the membership relations between roles. Any non-circular set of relationships is allowed.

Because user identities are cluster-wide, pg_auth_members is shared across all databases of a cluster: there is only one copy of pg_auth_members per cluster, not one per database.

Table 48-9. pg_auth_members Columns

Name	Type	References	Description
roleid	oid	pg_authid.oid	ID of a role that has a member
member	oid	pg_authid.oid	ID of a role that is a member of roleid
grantor	oid	pg_authid.oid	ID of the role that granted this membership
admin_option	bool		True if member can grant membership in roleid to others

48.10. pg_cast

The catalog pg_cast stores data type conversion paths, both built-in and user-defined.

It should be noted that pg_cast does not represent every type conversion that the system knows how to perform; only those that cannot be deduced from some generic rule. For example, casting between a domain and its base type is not explicitly represented in pg_cast. Another important exception is that "automatic I/O conversion casts", those performed using a data type's own I/O functions to convert to or from text or other string types, are not explicitly represented in pg_cast.

Table 48-10. pg_cast Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
castsource	oid	pg_type.oid	OID of the source data type
casttarget	oid	pg_type.oid	OID of the target data type
castfunc	oid	pg_proc.oid	The OID of the function to use to perform this cast. Zero is stored if the cast method doesn't require a function.

Name	Type	References	Description
castcontext	char		Indicates what contexts the cast can be invoked in. e means only as an explicit cast (using CAST or :: syntax). a means implicitly in assignment to a target column, as well as explicitly. i means implicitly in expressions, as well as the other cases.
castmethod	char		Indicates how the cast is performed. f means that the function specified in the castfunc field is used. i means that the input/output functions are used. b means that the types are binary-coercible, thus no conversion is required.

The cast functions listed in pg_cast must always take the cast source type as their first argument type, and return the cast destination type as their result type. A cast function can have up to three arguments. The second argument, if present, must be type integer; it receives the type modifier associated with the destination type, or -1 if there is none. The third argument, if present, must be type boolean; it receives true if the cast is an explicit cast, false otherwise.

It is legitimate to create a pg_cast entry in which the source and target types are the same, if the associated function takes more than one argument. Such entries represent "length coercion functions" that coerce values of the type to be legal for a particular type modifier value.

When a pg_cast entry has different source and target types and a function that takes more than one argument, it represents converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

48.11. pg_class

The catalog pg_class catalogs tables and most everything else that has columns or is otherwise similar to a table. This includes indexes (but see also pg_index), sequences, views, materialized views, composite types, and TOAST tables; see relkind. Below, when we mean all of these kinds of objects we speak of "relations". Not all columns are meaningful for all relation types.

Table 48-11. pg_class Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
relname	name		Name of the table, index, view, etc.
relnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this relation
reltype	oid	pg_type.oid	The OID of the data type that corresponds to this table's row type, if any (zero for indexes, which have no pg_type entry)
reloftype	oid	pg_type.oid	For typed tables, the OID of the underlying composite type, zero for all other relations
relowner	oid	pg_authid.oid	Owner of the relation
relam	oid	pg_am.oid	If this is an index, the access method used (B-tree, hash, etc.)
relfilenode	oid		Name of the on-disk file of this relation; zero means this is a "mapped" relation whose disk file name is determined by low-level state
reltablespace	oid	pg_tablespace.oid	The tablespace in which this relation is stored. If zero, the database's default tablespace is implied. (Not meaningful if the relation has no on-disk file.)
relpages	int4		Size of the on-disk representation of this table in pages (of size BLCKSZ). This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.

Name	Type	References	Description
reltuples	float4		Number of rows in the table. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
relallvisible	int4		Number of pages that are marked all-visible in the table's visibility map. This is only an estimate used by the planner. It is updated by VACUUM, ANALYZE, and a few DDL commands such as CREATE INDEX.
reltoastrelid	oid	pg_class.oid	OID of the TOAST table associated with this table, 0 if none. The TOAST table stores large attributes "out of line" in a secondary table.
relhasindex	bool		True if this is a table and it has (or recently had) any indexes
relisshared	bool		True if this table is shared across all databases in the cluster. Only certain system catalogs (such as pg_database) are shared.
relpersistence	char		p = permanent table, u = unlogged table, t = temporary table
relkind	char		r = ordinary table, i = index, S = sequence, v = view, m = materialized view, c = composite type, t = TOAST table, f = foreign table

Name	Type	References	Description
relnatts	int2		Number of user columns in the relation (system columns not counted). There must be this many corresponding entries in pg_attribute. See also pg_attribute.attnum.
relchecks	int2		Number of CHECK constraints on the table; see pg_constraint catalog
relhasoids	bool		True if we generate an OID for each row of the relation
relhaspkey	bool		True if the table has (or once had) a primary key
relhasrules	bool		True if table has (or once had) rules; see pg_rewrite catalog
relhastriggers	bool		True if table has (or once had) triggers; see pg_trigger catalog
relhassubclass	bool		True if table has (or once had) any inheritance children
relispopulated	bool		True if relation is populated (this is true for all relations other than some materialized views)
relreplident	char		Columns used to form "replica identity" for rows: d = default (primary key, if any), n = nothing, f = all columns i = index with indisreplident set, or default

Name	Type	References	Description
relfrozenxid	xid		All transaction IDs before this one have been replaced with a permanent ("frozen") transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_clog to be shrunk. Zero (InvalidTransactionId) if the relation is not a table.
relminmxid	xid		All multitransaction IDs before this one have been replaced by a transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent multitransaction ID ID wraparound or to allow pg_clog to be shrunk. Zero (InvalidTransactionId) if the relation is not a table.
relacl	aclitem[]		Access privileges; see GRANT and REVOKE for details
reloptions	text[]		Access-method-specific options, as "keyword=value" strings

Several of the Boolean flags in pg_class are maintained lazily: they are guaranteed to be true if that's the correct state, but may not be reset to false immediately when the condition is no longer true. For example, relhasindex is set by CREATE INDEX, but it is never cleared by DROP INDEX. Instead, VACUUM clears relhasindex if it finds the table has no indexes. This arrangement avoids race conditions and improves concurrency.

48.12. pg_collation

The catalog pg_collation describes the available collations, which are essentially mappings from

an SQL name to operating system locale categories. See Section 22.2 for more information.

Table 48-12. `pg_collation` Columns

Name	Type	References	Description
`oid`	`oid`		Row identifier (hidden attribute; must be explicitly selected)
`collname`	`name`		Collation name (unique per namespace and encoding)
`collnamespace`	`oid`	`pg_namespace.oid`	The OID of the namespace that contains this collation
`collowner`	`oid`	`pg_authid.oid`	Owner of the collation
`collencoding`	`int4`		Encoding in which the collation is applicable, or -1 if it works for any encoding
`collcollate`	`name`		`LC_COLLATE` for this collation object
`collctype`	`name`		`LC_CTYPE` for this collation object

Note that the unique key on this catalog is (`collname`, `collencoding`, `collnamespace`) not just (`collname`, `collnamespace`). PostgreSQL generally ignores all collations that do not have `collencoding` equal to either the current database's encoding or -1, and creation of new entries with the same name as an entry with `collencoding` = -1 is forbidden. Therefore it is sufficient to use a qualified SQL name (*`schema.name`*) to identify a collation, even though this is not unique according to the catalog definition. The reason for defining the catalog this way is that initdb fills it in at cluster initialization time with entries for all locales available on the system, so it must be able to hold entries for all encodings that might ever be used in the cluster.

In the `template0` database, it could be useful to create collations whose encoding does not match the database encoding, since they could match the encodings of databases later cloned from `template0`. This would currently have to be done manually.

48.13. `pg_constraint`

The catalog `pg_constraint` stores check, primary key, unique, foreign key, and exclusion constraints on tables. (Column constraints are not treated specially. Every column constraint is equivalent to some table constraint.) Not-null constraints are represented in the `pg_attribute` catalog, not here.

User-defined constraint triggers (created with `CREATE CONSTRAINT TRIGGER`) also give rise to an entry in this table.

Check constraints on domains are stored here, too.

Table 48-13. `pg_constraint` Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
conname	name		Constraint name (not necessarily unique!)
connamespace	oid	pg_namespace.oid	The OID of the namespace that contains this constraint
contype	char		c = check constraint, f = foreign key constraint, p = primary key constraint, u = unique constraint, t = constraint trigger, x = exclusion constraint
condeferrable	bool		Is the constraint deferrable?
condeferred	bool		Is the constraint deferred by default?
convalidated	bool		Has the constraint been validated? Currently, can only be false for foreign keys and CHECK constraints
conrelid	oid	pg_class.oid	The table this constraint is on; 0 if not a table constraint
contypid	oid	pg_type.oid	The domain this constraint is on; 0 if not a domain constraint
conindid	oid	pg_class.oid	The index supporting this constraint, if it's a unique, primary key, foreign key, or exclusion constraint; else 0
confrelid	oid	pg_class.oid	If a foreign key, the referenced table; else 0
confupdtype	char		Foreign key update action code: a = no action, r = restrict, c = cascade, n = set null, d = set default

Name	Type	References	Description
confdeltype	char		Foreign key deletion action code: a = no action, r = restrict, c = cascade, n = set null, d = set default
confmatchtype	char		Foreign key match type: f = full, p = partial, s = simple
conislocal	bool		This constraint is defined locally for the relation. Note that a constraint can be locally defined and inherited simultaneously.
coninhcount	int4		The number of direct inheritance ancestors this constraint has. A constraint with a nonzero number of ancestors cannot be dropped nor renamed.
connoinherit	bool		This constraint is defined locally for the relation. It is a non-inheritable constraint.
conkey	int2[]	pg_attribute.attnum	If a table constraint (including foreign keys, but not constraint triggers), list of the constrained columns
confkey	int2[]	pg_attribute.attnum	If a foreign key, list of the referenced columns
conpfeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = FK comparisons
conppeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for PK = PK comparisons
conffeqop	oid[]	pg_operator.oid	If a foreign key, list of the equality operators for FK = FK comparisons

Name	Type	References	Description
conexclop	oid[]	pg_operator.oid	If an exclusion constraint, list of the per-column exclusion operators
conbin	pg_node_tree		If a check constraint, an internal representation of the expression
consrc	text		If a check constraint, a human-readable representation of the expression

In the case of an exclusion constraint, conkey is only useful for constraint elements that are simple column references. For other cases, a zero appears in conkey and the associated index must be consulted to discover the expression that is constrained. (conkey thus has the same contents as pg_index.indkey for the index.)

Note: consrc is not updated when referenced objects change; for example, it won't track renaming of columns. Rather than relying on this field, it's best to use pg_get_constraintdef() to extract the definition of a check constraint.

Note: pg_class.relchecks needs to agree with the number of check-constraint entries found in this table for each relation.

48.14. pg_conversion

The catalog pg_conversion describes encoding conversion procedures. See CREATE CONVERSION for more information.

Table 48-14. pg_conversion Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
conname	name		Conversion name (unique within a namespace)
connamespace	oid	pg_namespace.oid	The OID of the namespace that contains this conversion

Name	Type	References	Description
conowner	oid	pg_authid.oid	Owner of the conversion
conforencoding	int4		Source encoding ID
contoencoding	int4		Destination encoding ID
conproc	regproc	pg_proc.oid	Conversion procedure
condefault	bool		True if this is the default conversion

48.15. pg_database

The catalog pg_database stores information about the available databases. Databases are created with the CREATE DATABASE command. Consult Chapter 21 for details about the meaning of some of the parameters.

Unlike most system catalogs, pg_database is shared across all databases of a cluster: there is only one copy of pg_database per cluster, not one per database.

Table 48-15. pg_database Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
datname	name		Database name
datdba	oid	pg_authid.oid	Owner of the database, usually the user who created it
encoding	int4		Character encoding for this database (pg_encoding_to_char() can translate this number to the encoding name)
datcollate	name		LC_COLLATE for this database
datctype	name		LC_CTYPE for this database
datistemplate	bool		If true, then this database can be cloned by any user with CREATEDB privileges; if false, then only superusers or the owner of the database can clone it.

Name	Type	References	Description
datallowconn	bool		If false then no one can connect to this database. This is used to protect the template0 database from being altered.
datconnlimit	int4		Sets maximum number of concurrent connections that can be made to this database. -1 means no limit.
datlastsysoid	oid		Last system OID in the database; useful particularly to pg_dump
datfrozenxid	xid		All transaction IDs before this one have been replaced with a permanent ("frozen") transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_clog to be shrunk. It is the minimum of the per-table pg_class.relfrozenxid values.
datminmxid	xid		All multitransaction IDs before this one have been replaced with a transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_clog to be shrunk. It is the minimum of the per-table pg_class.relminmxid values.

Name	Type	References	Description
dattablespace	oid	pg_tablespace.oid	The default tablespace for the database. Within this database, all tables for which pg_class.reltablespace is zero will be stored in this tablespace; in particular, all the non-shared system catalogs will be there.
datacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

48.16. pg_db_role_setting

The catalog pg_db_role_setting records the default values that have been set for run-time configuration variables, for each role and database combination.

Unlike most system catalogs, pg_db_role_setting is shared across all databases of a cluster: there is only one copy of pg_db_role_setting per cluster, not one per database.

Table 48-16. pg_db_role_setting Columns

Name	Type	References	Description
setdatabase	oid	pg_database.oid	The OID of the database the setting is applicable to, or zero if not database-specific
setrole	oid	pg_authid.oid	The OID of the role the setting is applicable to, or zero if not role-specific
setconfig	text[]		Defaults for run-time configuration variables

48.17. pg_default_acl

The catalog pg_default_acl stores initial privileges to be assigned to newly created objects.

Table 48-17. pg_default_acl Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)

Name	Type	References	Description
defaclrole	oid	pg_authid.oid	The OID of the role associated with this entry
defaclnamespace	oid	pg_namespace.oid	The OID of the namespace associated with this entry, or 0 if none
defaclobjtype	char		Type of object this entry is for: r = relation (table, view), S = sequence, f = function, T = type
defaclacl	aclitem[]		Access privileges that this type of object should have on creation

A pg_default_acl entry shows the initial privileges to be assigned to an object belonging to the indicated user. There are currently two types of entry: "global" entries with defaclnamespace = 0, and "per-schema" entries that reference a particular schema. If a global entry is present then it *overrides* the normal hard-wired default privileges for the object type. A per-schema entry, if present, represents privileges to be *added to* the global or hard-wired default privileges.

Note that when an ACL entry in another catalog is null, it is taken to represent the hard-wired default privileges for its object, *not* whatever might be in pg_default_acl at the moment. pg_default_acl is only consulted during object creation.

48.18. pg_depend

The catalog pg_depend records the dependency relationships between database objects. This information allows DROP commands to find which other objects must be dropped by DROP CASCADE or prevent dropping in the DROP RESTRICT case.

See also pg_shdepend, which performs a similar function for dependencies involving objects that are shared across a database cluster.

Table 48-18. pg_depend Columns

Name	Type	References	Description
classid	oid	pg_class.oid	The OID of the system catalog the dependent object is in
objid	oid	any OID column	The OID of the specific dependent object

Name	Type	References	Description
objsubid	int4		For a table column, this is the column number (the objid and classid refer to the table itself). For all other object types, this column is zero.
refclassid	oid	pg_class.oid	The OID of the system catalog the referenced object is in
refobjid	oid	any OID column	The OID of the specific referenced object
refobjsubid	int4		For a table column, this is the column number (the refobjid and refclassid refer to the table itself). For all other object types, this column is zero.
deptype	char		A code defining the specific semantics of this dependency relationship; see text

In all cases, a pg_depend entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by deptype:

DEPENDENCY_NORMAL (n)

A normal relationship between separately-created objects. The dependent object can be dropped without affecting the referenced object. The referenced object can only be dropped by specifying CASCADE, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.

DEPENDENCY_AUTO (a)

The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of RESTRICT or CASCADE mode) if the referenced object is dropped. Example: a named constraint on a table is made autodependent on the table, so that it will go away if the table is dropped.

DEPENDENCY_INTERNAL (i)

The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation. A DROP of the dependent object will be disallowed outright (we'll tell the user to issue a DROP against the referenced object, instead). A DROP of the referenced object will be propagated through to drop the dependent object whether CASCADE is specified or not. Example: a trigger that's created to enforce a foreign-key constraint is made internally dependent on the constraint's pg_constraint entry.

DEPENDENCY_EXTENSION (e)

The dependent object is a member of the *extension* that is the referenced object (see

pg_extension). The dependent object can be dropped only via DROP EXTENSION on the referenced object. Functionally this dependency type acts the same as an internal dependency, but it's kept separate for clarity and to simplify pg_dump.

DEPENDENCY_PIN (p)

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by initdb. The columns for the dependent object contain zeroes.

Other dependency flavors might be needed in future.

48.19. pg_description

The catalog pg_description stores optional descriptions (comments) for each database object. Descriptions can be manipulated with the COMMENT command and viewed with psql's \d commands. Descriptions of many built-in system objects are provided in the initial contents of pg_description.

See also pg_shdescription, which performs a similar function for descriptions involving objects that are shared across a database cluster.

Table 48-19. pg_description Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this description pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in
objsubid	int4		For a comment on a table column, this is the column number (the objoid and classoid refer to the table itself). For all other object types, this column is zero.
description	text		Arbitrary text that serves as the description of this object

48.20. pg_enum

The pg_enum catalog contains entries showing the values and labels for each enum type. The internal representation of a given enum value is actually the OID of its associated row in pg_enum.

Table 48-20. pg_enum Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
enumtypid	oid	pg_type.oid	The OID of the pg_type entry owning this enum value
enumsortorder	float4		The sort position of this enum value within its enum type
enumlabel	name		The textual label for this enum value

The OIDs for pg_enum rows follow a special rule: even-numbered OIDs are guaranteed to be ordered in the same way as the sort ordering of their enum type. That is, if two even OIDs belong to the same enum type, the smaller OID must have the smaller enumsortorder value. Odd-numbered OID values need bear no relationship to the sort order. This rule allows the enum comparison routines to avoid catalog lookups in many common cases. The routines that create and alter enum types attempt to assign even OIDs to enum values whenever possible.

When an enum type is created, its members are assigned sort-order positions 1..*n*. But members added later might be given negative or fractional values of enumsortorder. The only requirement on these values is that they be correctly ordered and unique within each enum type.

48.21. pg_event_trigger

The catalog pg_event_trigger stores event triggers. See Chapter 37 for more information.

Table 48-21. pg_event_trigger Columns

Name	Type	References	Description
evtname	name		Trigger name (must be unique)
evtevent	name		Identifies the event for which this trigger fires
evtowner	oid	pg_authid.oid	Owner of the event trigger
evtfoid	oid	pg_proc.oid	The function to be called
evtenabled	char		Controls in which session_replication_role modes the event trigger fires. O = trigger fires in "origin" and "local" modes, D = trigger is disabled, R = trigger fires in "replica" mode, A = trigger fires always.

Name	Type	References	Description
evttags	text[]		Command tags for which this trigger will fire. If NULL, the firing of this trigger is not restricted on the basis of the command tag.

48.22. pg_extension

The catalog pg_extension stores information about the installed extensions. See Section 35.15 for details about extensions.

Table 48-22. pg_extension Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
extname	name		Name of the extension
extowner	oid	pg_authid.oid	Owner of the extension
extnamespace	oid	pg_namespace.oid	Schema containing the extension's exported objects
extrelocatable	bool		True if extension can be relocated to another schema
extversion	text		Version name for the extension
extconfig	oid[]	pg_class.oid	Array of regclass OIDs for the extension's configuration table(s), or NULL if none
extcondition	text[]		Array of WHERE-clause filter conditions for the extension's configuration table(s), or NULL if none

Note that unlike most catalogs with a "namespace" column, extnamespace is not meant to imply that the extension belongs to that schema. Extension names are never schema-qualified. Rather, extnamespace indicates the schema that contains most or all of the extension's objects. If extrelocatable is true, then this schema must in fact contain all schema-qualifiable objects belonging to the extension.

48.23. pg_foreign_data_wrapper

The catalog pg_foreign_data_wrapper stores foreign-data wrapper definitions. A foreign-data wrapper is the mechanism by which external data, residing on foreign servers, is accessed.

Table 48-23. pg_foreign_data_wrapper Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
fdwname	name		Name of the foreign-data wrapper
fdwowner	oid	pg_authid.oid	Owner of the foreign-data wrapper
fdwhandler	oid	pg_proc.oid	References a handler function that is responsible for supplying execution routines for the foreign-data wrapper. Zero if no handler is provided
fdwvalidator	oid	pg_proc.oid	References a validator function that is responsible for checking the validity of the options given to the foreign-data wrapper, as well as options for foreign servers and user mappings using the foreign-data wrapper. Zero if no validator is provided
fdwacl	aclitem[]		Access privileges; see GRANT and REVOKE for details
fdwoptions	text[]		Foreign-data wrapper specific options, as "keyword=value" strings

48.24. pg_foreign_server

The catalog pg_foreign_server stores foreign server definitions. A foreign server describes a source of external data, such as a remote server. Foreign servers are accessed via foreign-data wrappers.

Table 48-24. `pg_foreign_server` Columns

Name	Type	References	Description
`oid`	`oid`		Row identifier (hidden attribute; must be explicitly selected)
`srvname`	`name`		Name of the foreign server
`srvowner`	`oid`	`pg_authid.oid`	Owner of the foreign server
`srvfdw`	`oid`	`pg_foreign_data_wrapper.oid`	OID of the foreign-data wrapper of this foreign server
`srvtype`	`text`		Type of the server (optional)
`srvversion`	`text`		Version of the server (optional)
`srvacl`	`aclitem[]`		Access privileges; see GRANT and REVOKE for details
`srvoptions`	`text[]`		Foreign server specific options, as "keyword=value" strings

48.25. `pg_foreign_table`

The catalog `pg_foreign_table` contains auxiliary information about foreign tables. A foreign table is primarily represented by a `pg_class` entry, just like a regular table. Its `pg_foreign_table` entry contains the information that is pertinent only to foreign tables and not any other kind of relation.

Table 48-25. `pg_foreign_table` Columns

Name	Type	References	Description
`ftrelid`	`oid`	`pg_class.oid`	OID of the `pg_class` entry for this foreign table
`ftserver`	`oid`	`pg_foreign_server.oid`	OID of the foreign server for this foreign table
`ftoptions`	`text[]`		Foreign table options, as "keyword=value" strings

48.26. pg_index

The catalog pg_index contains part of the information about indexes. The rest is mostly in pg_class.

Table 48-26. pg_index Columns

Name	Type	References	Description
indexrelid	oid	pg_class.oid	The OID of the pg_class entry for this index
indrelid	oid	pg_class.oid	The OID of the pg_class entry for the table this index is for
indnatts	int2		The number of columns in the index (duplicates pg_class.relnatts)
indisunique	bool		If true, this is a unique index
indisprimary	bool		If true, this index represents the primary key of the table (indisunique should always be true when this is true)
indisexclusion	bool		If true, this index supports an exclusion constraint
indimmediate	bool		If true, the uniqueness check is enforced immediately on insertion (irrelevant if indisunique is not true)
indisclustered	bool		If true, the table was last clustered on this index

Name	Type	References	Description
indisvalid	bool		If true, the index is currently valid for queries. False means the index is possibly incomplete: it must still be modified by INSERT/UPDATE operations, but it cannot safely be used for queries. If it is unique, the uniqueness property is not guaranteed true either.
indcheckxmin	bool		If true, queries must not use the index until the xmin of this pg_index row is below their TransactionXmin event horizon, because the table may contain broken HOT chains with incompatible rows that they can see
indisready	bool		If true, the index is currently ready for inserts. False means the index must be ignored by INSERT/UPDATE operations.
indislive	bool		If false, the index is in process of being dropped, and should be ignored for all purposes (including HOT-safety decisions)
indisreplident	bool		If true this index has been chosen as "replica identity" using ALTER TABLE ... REPLICA IDENTITY USING INDEX ...

Name	Type	References	Description
indkey	int2vector	pg_attribute.attnum	This is an array of indnatts values that indicate which table columns this index indexes. For example a value of 1 3 would mean that the first and the third table columns make up the index key. A zero in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference.
indcollation	oidvector	pg_collation.oid	For each column in the index key, this contains the OID of the collation to use for the index.
indclass	oidvector	pg_opclass.oid	For each column in the index key, this contains the OID of the operator class to use. See pg_opclass for details.
indoption	int2vector		This is an array of indnatts values that store per-column flag bits. The meaning of the bits is defined by the index's access method.
indexprs	pg_node_tree		Expression trees (in nodeToString() representation) for index attributes that are not simple column references. This is a list with one element for each zero entry in indkey. Null if all index attributes are simple references.

Name	Type	References	Description
indpred	pg_node_tree		Expression tree (in nodeToString() representation) for partial index predicate. Null if not a partial index.

48.27. pg_inherits

The catalog pg_inherits records information about table inheritance hierarchies. There is one entry for each direct child table in the database. (Indirect inheritance can be determined by following chains of entries.)

Table 48-27. pg_inherits Columns

Name	Type	References	Description
inhrelid	oid	pg_class.oid	The OID of the child table
inhparent	oid	pg_class.oid	The OID of the parent table
inhseqno	int4		If there is more than one direct parent for a child table (multiple inheritance), this number tells the order in which the inherited columns are to be arranged. The count starts at 1.

48.28. pg_language

The catalog pg_language registers languages in which you can write functions or stored procedures. See CREATE LANGUAGE and Chapter 39 for more information about language handlers.

Table 48-28. pg_language Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
lanname	name		Name of the language
lanowner	oid	pg_authid.oid	Owner of the language

Name	Type	References	Description
lanispl	bool		This is false for internal languages (such as SQL) and true for user-defined languages. Currently, pg_dump still uses this to determine which languages need to be dumped, but this might be replaced by a different mechanism in the future.
lanpltrusted	bool		True if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only superusers can create functions in untrusted languages.
lanplcallfoid	oid	pg_proc.oid	For noninternal languages this references the language handler, which is a special function that is responsible for executing all functions that are written in the particular language
laninline	oid	pg_proc.oid	This references a function that is responsible for executing "inline" anonymous code blocks (DO blocks). Zero if inline blocks are not supported.
lanvalidator	oid	pg_proc.oid	This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. Zero if no validator is provided.

Name	Type	References	Description
lanacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

48.29. pg_largeobject

The catalog pg_largeobject holds the data making up "large objects". A large object is identified by an OID assigned when it is created. Each large object is broken into segments or "pages" small enough to be conveniently stored as rows in pg_largeobject. The amount of data per page is defined to be LOBLKSIZE (which is currently BLCKSZ/4, or typically 2 kB).

Prior to PostgreSQL 9.0, there was no permission structure associated with large objects. As a result, pg_largeobject was publicly readable and could be used to obtain the OIDs (and contents) of all large objects in the system. This is no longer the case; use pg_largeobject_metadata to obtain a list of large object OIDs.

Table 48-29. pg_largeobject Columns

Name	Type	References	Description
loid	oid	pg_largeobject_metadata.oid	Identifier of the large object that includes this page
pageno	int4		Page number of this page within its large object (counting from zero)
data	bytea		Actual data stored in the large object. This will never be more than LOBLKSIZE bytes and might be less.

Each row of pg_largeobject holds data for one page of a large object, beginning at byte offset (pageno * LOBLKSIZE) within the object. The implementation allows sparse storage: pages might be missing, and might be shorter than LOBLKSIZE bytes even if they are not the last page of the object. Missing regions within a large object read as zeroes.

48.30. pg_largeobject_metadata

The catalog pg_largeobject_metadata holds metadata associated with large objects. The actual large object data is stored in pg_largeobject.

Table 48-30. pg_largeobject_metadata Columns

Name	Type	References	Description

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
lomowner	oid	pg_authid.oid	Owner of the large object
lomacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

48.31. pg_namespace

The catalog pg_namespace stores namespaces. A namespace is the structure underlying SQL schemas: each namespace can have a separate collection of relations, types, etc. without name conflicts.

Table 48-31. pg_namespace Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
nspname	name		Name of the namespace
nspowner	oid	pg_authid.oid	Owner of the namespace
nspacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

48.32. pg_opclass

The catalog pg_opclass defines index access method operator classes. Each operator class defines semantics for index columns of a particular data type and a particular index access method. An operator class essentially specifies that a particular operator family is applicable to a particular indexable column data type. The set of operators from the family that are actually usable with the indexed column are whichever ones accept the column's data type as their left-hand input.

Operator classes are described at length in Section 35.14.

Table 48-32. pg_opclass Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)

Name	Type	References	Description
opcmethod	oid	pg_am.oid	Index access method operator class is for
opcname	name		Name of this operator class
opcnamespace	oid	pg_namespace.oid	Namespace of this operator class
opcowner	oid	pg_authid.oid	Owner of the operator class
opcfamily	oid	pg_opfamily.oid	Operator family containing the operator class
opcintype	oid	pg_type.oid	Data type that the operator class indexes
opcdefault	bool		True if this operator class is the default for opcintype
opckeytype	oid	pg_type.oid	Type of data stored in index, or zero if same as opcintype

An operator class's opcmethod must match the opfmethod of its containing operator family. Also, there must be no more than one pg_opclass row having opcdefault true for any given combination of opcmethod and opcintype.

48.33. pg_operator

The catalog pg_operator stores information about operators. See CREATE OPERATOR and Section 35.12 for more information.

Table 48-33. pg_operator Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
oprname	name		Name of the operator
oprnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this operator
oprowner	oid	pg_authid.oid	Owner of the operator
oprkind	char		b = infix ("both"), l = prefix ("left"), r = postfix ("right")
oprcanmerge	bool		This operator supports merge joins

Name	Type	References	Description
oprcanhash	bool		This operator supports hash joins
oprleft	oid	pg_type.oid	Type of the left operand
oprright	oid	pg_type.oid	Type of the right operand
oprresult	oid	pg_type.oid	Type of the result
oprcom	oid	pg_operator.oid	Commutator of this operator, if any
oprnegate	oid	pg_operator.oid	Negator of this operator, if any
oprcode	regproc	pg_proc.oid	Function that implements this operator
oprrest	regproc	pg_proc.oid	Restriction selectivity estimation function for this operator
oprjoin	regproc	pg_proc.oid	Join selectivity estimation function for this operator

Unused column contain zeroes. For example, oprleft is zero for a prefix operator.

48.34. pg_opfamily

The catalog pg_opfamily defines operator families. Each operator family is a collection of operators and associated support routines that implement the semantics specified for a particular index access method. Furthermore, the operators in a family are all "compatible", in a way that is specified by the access method. The operator family concept allows cross-data-type operators to be used with indexes and to be reasoned about using knowledge of access method semantics.

Operator families are described at length in Section 35.14.

Table 48-34. pg_opfamily Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
opfmethod	oid	pg_am.oid	Index access method operator family is for
opfname	name		Name of this operator family
opfnamespace	oid	pg_namespace.oid	Namespace of this operator family
opfowner	oid	pg_authid.oid	Owner of the operator family

The majority of the information defining an operator family is not in its pg_opfamily row, but in the associated rows in pg_amop, pg_amproc, and pg_opclass.

48.35. pg_pltemplate

The catalog pg_pltemplate stores "template" information for procedural languages. A template for a language allows the language to be created in a particular database by a simple CREATE LANGUAGE command, with no need to specify implementation details.

Unlike most system catalogs, pg_pltemplate is shared across all databases of a cluster: there is only one copy of pg_pltemplate per cluster, not one per database. This allows the information to be accessible in each database as it is needed.

Table 48-35. pg_pltemplate Columns

Name	Type	Description
tmplname	name	Name of the language this template is for
tmpltrusted	boolean	True if language is considered trusted
tmpldbacreate	boolean	True if language may be created by a database owner
tmplhandler	text	Name of call handler function
tmplinline	text	Name of anonymous-block handler function, or null if none
tmplvalidator	text	Name of validator function, or null if none
tmpllibrary	text	Path of shared library that implements language
tmplacl	aclitem[]	Access privileges for template (not actually used)

There are not currently any commands that manipulate procedural language templates; to change the built-in information, a superuser must modify the table using ordinary INSERT, DELETE, or UPDATE commands.

> **Note:** It is likely that pg_pltemplate will be removed in some future release of PostgreSQL, in favor of keeping this knowledge about procedural languages in their respective extension installation scripts.

48.36. pg_proc

The catalog pg_proc stores information about functions (or procedures). See CREATE FUNCTION and Section 35.3 for more information.

The table contains data for aggregate functions as well as plain functions. If proisagg is true, there should be a matching row in pg_aggregate.

Table 48-36. pg_proc Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
proname	name		Name of the function
pronamespace	oid	pg_namespace.oid	The OID of the namespace that contains this function
proowner	oid	pg_authid.oid	Owner of the function
prolang	oid	pg_language.oid	Implementation language or call interface of this function
procost	float4		Estimated execution cost (in units of cpu_operator_cost); if proretset, this is cost per row returned
prorows	float4		Estimated number of result rows (zero if not proretset)
provariadic	oid	pg_type.oid	Data type of the variadic array parameter's elements, or zero if the function does not have a variadic parameter
protransform	regproc	pg_proc.oid	Calls to this function can be simplified by this other function (see Section 35.9.11)
proisagg	bool		Function is an aggregate function
proiswindow	bool		Function is a window function
prosecdef	bool		Function is a security definer (i.e., a "setuid" function)

Name	Type	References	Description
proleakproof	bool		The function has no side effects. No information about the arguments is conveyed except via the return value. Any function that might throw an error depending on the values of its arguments is not leak-proof.
proisstrict	bool		Function returns null if any call argument is null. In that case the function won't actually be called at all. Functions that are not "strict" must be prepared to handle null inputs.
proretset	bool		Function returns a set (i.e., multiple values of the specified data type)
provolatile	char		provolatile tells whether the function's result depends only on its input arguments, or is affected by outside factors. It is i for "immutable" functions, which always deliver the same result for the same inputs. It is s for "stable" functions, whose results (for fixed inputs) do not change within a scan. It is v for "volatile" functions, whose results might change at any time. (Use v also for functions with side-effects, so that calls to them cannot get optimized away.)
pronargs	int2		Number of input arguments
pronargdefaults	int2		Number of arguments that have defaults

Name	Type	References	Description
prorettype	oid	pg_type.oid	Data type of the return value
proargtypes	oidvector	pg_type.oid	An array with the data types of the function arguments. This includes only input arguments (including INOUT and VARIADIC arguments), and thus represents the call signature of the function.
proallargtypes	oid[]	pg_type.oid	An array with the data types of the function arguments. This includes all arguments (including OUT and INOUT arguments); however, if all the arguments are IN arguments, this field will be null. Note that subscripting is 1-based, whereas for historical reasons proargtypes is subscripted from 0.
proargmodes	char[]		An array with the modes of the function arguments, encoded as i for IN arguments, o for OUT arguments, b for INOUT arguments, v for VARIADIC arguments, t for TABLE arguments. If all the arguments are IN arguments, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.

Name	Type	References	Description
proargnames	text[]		An array with the names of the function arguments. Arguments without a name are set to empty strings in the array. If none of the arguments have a name, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.
proargdefaults	pg_node_tree		Expression trees (in nodeToString() representation) for default values. This is a list with pronargdefaults elements, corresponding to the last *N* *input* arguments (i.e., the last *N* proargtypes positions). If none of the arguments have defaults, this field will be null.
prosrc	text		This tells the function handler how to invoke the function. It might be the actual source code of the function for interpreted languages, a link symbol, a file name, or just about anything else, depending on the implementation language/call convention.
probin	text		Additional information about how to invoke the function. Again, the interpretation is language-specific.
proconfig	text[]		Function's local settings for run-time configuration variables

Name	Type	References	Description
proacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

For compiled functions, both built-in and dynamically loaded, prosrc contains the function's C-language name (link symbol). For all other currently-known language types, prosrc contains the function's source text. probin is unused except for dynamically-loaded C functions, for which it gives the name of the shared library file containing the function.

48.37. pg_range

The catalog pg_range stores information about range types. This is in addition to the types' entries in pg_type.

Table 48-37. pg_range Columns

Name	Type	References	Description
rngtypid	oid	pg_type.oid	OID of the range type
rngsubtype	oid	pg_type.oid	OID of the element type (subtype) of this range type
rngcollation	oid	pg_collation.oid	OID of the collation used for range comparisons, or 0 if none
rngsubopc	oid	pg_opclass.oid	OID of the subtype's operator class used for range comparisons
rngcanonical	regproc	pg_proc.oid	OID of the function to convert a range value into canonical form, or 0 if none
rngsubdiff	regproc	pg_proc.oid	OID of the function to return the difference between two element values as double precision, or 0 if none

rngsubopc (plus rngcollation, if the element type is collatable) determines the sort ordering used by the range type. rngcanonical is used when the element type is discrete. rngsubdiff is optional but should be supplied to improve performance of GiST indexes on the range type.

48.38. pg_rewrite

The catalog pg_rewrite stores rewrite rules for tables and views.

Table 48-38. `pg_rewrite` Columns

Name	Type	References	Description
`oid`	`oid`		Row identifier (hidden attribute; must be explicitly selected)
`rulename`	`name`		Rule name
`ev_class`	`oid`	`pg_class.oid`	The table this rule is for
`ev_type`	`char`		Event type that the rule is for: 1 = `SELECT`, 2 = `UPDATE`, 3 = `INSERT`, 4 = `DELETE`
`ev_enabled`	`char`		Controls in which session_replication_role modes the rule fires. `O` = rule fires in "origin" and "local" modes, `D` = rule is disabled, `R` = rule fires in "replica" mode, `A` = rule fires always.
`is_instead`	`bool`		True if the rule is an `INSTEAD` rule
`ev_qual`	`pg_node_tree`		Expression tree (in the form of a `nodeToString()` representation) for the rule's qualifying condition
`ev_action`	`pg_node_tree`		Query tree (in the form of a `nodeToString()` representation) for the rule's action

Note: `pg_class.relhasrules` must be true if a table has any rules in this catalog.

48.39. `pg_replication_slots`

The `pg_replication_slots` view provides a listing of all replication slots that currently exist on the database cluster, along with their current state.

For more on replication slots, see Section 25.2.6 and Chapter 46.

Table 48-39. `pg_replication_slots` Columns

Name	Type	References	Description

Name	Type	References	Description
slot_name	name		A unique, cluster-wide identifier for the replication slot
plugin	name		The base name of the shared object containing the output plugin this logical slot is using, or null for physical slots.
slot_type	text		The slot type - physical or logical
datoid	oid	pg_database.oid	The OID of the database this slot is associated with, or null. Only logical slots have an associated database.
database	text	pg_database.datname	The name of the database this slot is associated with, or null. Only logical slots have an associated database.
active	boolean		True if this slot is currently actively being used
xmin	xid		The oldest transaction that this slot needs the database to retain. VACUUM cannot remove tuples deleted by any later transaction.
catalog_xmin	xid		The oldest transaction affecting the system catalogs that this slot needs the database to retain. VACUUM cannot remove catalog tuples deleted by any later transaction.
restart_lsn	pg_lsn		The address (LSN) of oldest WAL which still might be required by the consumer of this slot and thus won't be automatically removed during checkpoints.

48.40. pg_seclabel

The catalog pg_seclabel stores security labels on database objects. Security labels can be manipulated with the SECURITY LABEL command. For an easier way to view security labels, see Section 48.66.

See also pg_shseclabel, which performs a similar function for security labels of database objects that are shared across a database cluster.

Table 48-40. pg_seclabel Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this security label pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in
objsubid	int4		For a security label on a table column, this is the column number (the objoid and classoid refer to the table itself). For all other object types, this column is zero.
provider	text		The label provider associated with this label.
label	text		The security label applied to this object.

48.41. pg_shdepend

The catalog pg_shdepend records the dependency relationships between database objects and shared objects, such as roles. This information allows PostgreSQL to ensure that those objects are unreferenced before attempting to delete them.

See also pg_depend, which performs a similar function for dependencies involving objects within a single database.

Unlike most system catalogs, pg_shdepend is shared across all databases of a cluster: there is only one copy of pg_shdepend per cluster, not one per database.

Table 48-41. pg_shdepend Columns

Name	Type	References	Description

Name	Type	References	Description
dbid	oid	pg_database.oid	The OID of the database the dependent object is in, or zero for a shared object
classid	oid	pg_class.oid	The OID of the system catalog the dependent object is in
objid	oid	any OID column	The OID of the specific dependent object
objsubid	int4		For a table column, this is the column number (the objid and classid refer to the table itself). For all other object types, this column is zero.
refclassid	oid	pg_class.oid	The OID of the system catalog the referenced object is in (must be a shared catalog)
refobjid	oid	any OID column	The OID of the specific referenced object
deptype	char		A code defining the specific semantics of this dependency relationship; see text

In all cases, a pg_shdepend entry indicates that the referenced object cannot be dropped without also dropping the dependent object. However, there are several subflavors identified by deptype:

SHARED_DEPENDENCY_OWNER (o)

The referenced object (which must be a role) is the owner of the dependent object.

SHARED_DEPENDENCY_ACL (a)

The referenced object (which must be a role) is mentioned in the ACL (access control list, i.e., privileges list) of the dependent object. (A SHARED_DEPENDENCY_ACL entry is not made for the owner of the object, since the owner will have a SHARED_DEPENDENCY_OWNER entry anyway.)

SHARED_DEPENDENCY_PIN (p)

There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by initdb. The columns for the dependent object contain zeroes.

Other dependency flavors might be needed in future. Note in particular that the current definition only supports roles as referenced objects.

48.42. pg_shdescription

The catalog pg_shdescription stores optional descriptions (comments) for shared database objects. Descriptions can be manipulated with the COMMENT command and viewed with psql's \d commands.

See also pg_description, which performs a similar function for descriptions involving objects within a single database.

Unlike most system catalogs, pg_shdescription is shared across all databases of a cluster: there is only one copy of pg_shdescription per cluster, not one per database.

Table 48-42. pg_shdescription Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this description pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in
description	text		Arbitrary text that serves as the description of this object

48.43. pg_shseclabel

The catalog pg_shseclabel stores security labels on shared database objects. Security labels can be manipulated with the SECURITY LABEL command. For an easier way to view security labels, see Section 48.66.

See also pg_seclabel, which performs a similar function for security labels involving objects within a single database.

Unlike most system catalogs, pg_shseclabel is shared across all databases of a cluster: there is only one copy of pg_shseclabel per cluster, not one per database.

Table 48-43. pg_shseclabel Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this security label pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in
provider	text		The label provider associated with this label.

Name	Type	References	Description
label	text		The security label applied to this object.

48.44. pg_statistic

The catalog pg_statistic stores statistical data about the contents of the database. Entries are created by ANALYZE and subsequently used by the query planner. Note that all the statistical data is inherently approximate, even assuming that it is up-to-date.

Normally there is one entry, with stainherit = false, for each table column that has been analyzed. If the table has inheritance children, a second entry with stainherit = true is also created. This row represents the column's statistics over the inheritance tree, i.e., statistics for the data you'd see with SELECT *column* FROM *table**, whereas the stainherit = false row represents the results of SELECT *column* FROM ONLY *table*.

pg_statistic also stores statistical data about the values of index expressions. These are described as if they were actual data columns; in particular, starelid references the index. No entry is made for an ordinary non-expression index column, however, since it would be redundant with the entry for the underlying table column. Currently, entries for index expressions always have stainherit = false.

Since different kinds of statistics might be appropriate for different kinds of data, pg_statistic is designed not to assume very much about what sort of statistics it stores. Only extremely general statistics (such as nullness) are given dedicated columns in pg_statistic. Everything else is stored in "slots", which are groups of associated columns whose content is identified by a code number in one of the slot's columns. For more information see src/include/catalog/pg_statistic.h.

pg_statistic should not be readable by the public, since even statistical information about a table's contents might be considered sensitive. (Example: minimum and maximum values of a salary column might be quite interesting.) pg_stats is a publicly readable view on pg_statistic that only exposes information about those tables that are readable by the current user.

Table 48-44. pg_statistic Columns

Name	Type	References	Description
starelid	oid	pg_class.oid	The table or index that the described column belongs to
staattnum	int2	pg_attribute.attnum	The number of the described column
stainherit	bool		If true, the stats include inheritance child columns, not just the values in the specified relation
stanullfrac	float4		The fraction of the column's entries that are null

Name	Type	References	Description
stawidth	int4		The average stored width, in bytes, of nonnull entries
stadistinct	float4		The number of distinct nonnull data values in the column. A value greater than zero is the actual number of distinct values. A value less than zero is the negative of a multiplier for the number of rows in the table; for example, a column in which values appear about twice on the average could be represented by stadistinct = -0.5. A zero value means the number of distinct values is unknown.
stakind*N*	int2		A code number indicating the kind of statistics stored in the *N*th "slot" of the pg_statistic row.
staop*N*	oid	pg_operator.oid	An operator used to derive the statistics stored in the *N*th "slot". For example, a histogram slot would show the < operator that defines the sort order of the data.
stanumbers*N*	float4[]		Numerical statistics of the appropriate kind for the *N*th "slot", or null if the slot kind does not involve numerical values

Name	Type	References	Description
stavalues*N*	anyarray		Column data values of the appropriate kind for the *N*th "slot", or null if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, or a related type such as an array's element type, so there is no way to define these columns' type more specifically than anyarray.

48.45. pg_tablespace

The catalog pg_tablespace stores information about the available tablespaces. Tables can be placed in particular tablespaces to aid administration of disk layout.

Unlike most system catalogs, pg_tablespace is shared across all databases of a cluster: there is only one copy of pg_tablespace per cluster, not one per database.

Table 48-45. pg_tablespace Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
spcname	name		Tablespace name
spcowner	oid	pg_authid.oid	Owner of the tablespace, usually the user who created it
spcacl	aclitem[]		Access privileges; see GRANT and REVOKE for details
spcoptions	text[]		Tablespace-level options, as "keyword=value" strings

48.46. pg_trigger

The catalog pg_trigger stores triggers on tables and views. See CREATE TRIGGER for more information.

Table 48-46. `pg_trigger` Columns

Name	Type	References	Description
`oid`	`oid`		Row identifier (hidden attribute; must be explicitly selected)
`tgrelid`	`oid`	`pg_class.oid`	The table this trigger is on
`tgname`	`name`		Trigger name (must be unique among triggers of same table)
`tgfoid`	`oid`	`pg_proc.oid`	The function to be called
`tgtype`	`int2`		Bit mask identifying trigger firing conditions
`tgenabled`	`char`		Controls in which session_replication_role modes the trigger fires. `O` = trigger fires in "origin" and "local" modes, `D` = trigger is disabled, `R` = trigger fires in "replica" mode, `A` = trigger fires always.
`tgisinternal`	`bool`		True if trigger is internally generated (usually, to enforce the constraint identified by `tgconstraint`)
`tgconstrrelid`	`oid`	`pg_class.oid`	The table referenced by a referential integrity constraint
`tgconstrindid`	`oid`	`pg_class.oid`	The index supporting a unique, primary key, referential integrity, or exclusion constraint
`tgconstraint`	`oid`	`pg_constraint.oid`	The `pg_constraint` entry associated with the trigger, if any
`tgdeferrable`	`bool`		True if constraint trigger is deferrable
`tginitdeferred`	`bool`		True if constraint trigger is initially deferred
`tgnargs`	`int2`		Number of argument strings passed to trigger function

Name	Type	References	Description
tgattr	int2vector	pg_attribute.attnum	Column numbers, if trigger is column-specific; otherwise an empty array
tgargs	bytea		Argument strings to pass to trigger, each NULL-terminated
tgqual	pg_node_tree		Expression tree (in nodeToString() representation) for the trigger's WHEN condition, or null if none

Currently, column-specific triggering is supported only for UPDATE events, and so tgattr is relevant only for that event type. tgtype might contain bits for other event types as well, but those are presumed to be table-wide regardless of what is in tgattr.

Note: When tgconstraint is nonzero, tgconstrrelid, tgconstrindid, tgdeferrable, and tginitdeferred are largely redundant with the referenced pg_constraint entry. However, it is possible for a non-deferrable trigger to be associated with a deferrable constraint: foreign key constraints can have some deferrable and some non-deferrable triggers.

Note: pg_class.relhastriggers must be true if a relation has any triggers in this catalog.

48.47. pg_ts_config

The pg_ts_config catalog contains entries representing text search configurations. A configuration specifies a particular text search parser and a list of dictionaries to use for each of the parser's output token types. The parser is shown in the pg_ts_config entry, but the token-to-dictionary mapping is defined by subsidiary entries in pg_ts_config_map.

PostgreSQL's text search features are described at length in Chapter 12.

Table 48-47. pg_ts_config Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
cfgname	name		Text search configuration name

Name	Type	References	Description
cfgnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this configuration
cfgowner	oid	pg_authid.oid	Owner of the configuration
cfgparser	oid	pg_ts_parser.oid	The OID of the text search parser for this configuration

48.48. pg_ts_config_map

The pg_ts_config_map catalog contains entries showing which text search dictionaries should be consulted, and in what order, for each output token type of each text search configuration's parser.

PostgreSQL's text search features are described at length in Chapter 12.

Table 48-48. pg_ts_config_map Columns

Name	Type	References	Description
mapcfg	oid	pg_ts_config.oid	The OID of the pg_ts_config entry owning this map entry
maptokentype	integer		A token type emitted by the configuration's parser
mapseqno	integer		Order in which to consult this entry (lower mapseqnos first)
mapdict	oid	pg_ts_dict.oid	The OID of the text search dictionary to consult

48.49. pg_ts_dict

The pg_ts_dict catalog contains entries defining text search dictionaries. A dictionary depends on a text search template, which specifies all the implementation functions needed; the dictionary itself provides values for the user-settable parameters supported by the template. This division of labor allows dictionaries to be created by unprivileged users. The parameters are specified by a text string dictinitoption, whose format and meaning vary depending on the template.

PostgreSQL's text search features are described at length in Chapter 12.

Table 48-49. pg_ts_dict Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
dictname	name		Text search dictionary name
dictnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this dictionary
dictowner	oid	pg_authid.oid	Owner of the dictionary
dicttemplate	oid	pg_ts_template.oid	The OID of the text search template for this dictionary
dictinitoption	text		Initialization option string for the template

48.50. pg_ts_parser

The pg_ts_parser catalog contains entries defining text search parsers. A parser is responsible for splitting input text into lexemes and assigning a token type to each lexeme. Since a parser must be implemented by C-language-level functions, creation of new parsers is restricted to database superusers.

PostgreSQL's text search features are described at length in Chapter 12.

Table 48-50. pg_ts_parser Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
prsname	name		Text search parser name
prsnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this parser
prsstart	regproc	pg_proc.oid	OID of the parser's startup function
prstoken	regproc	pg_proc.oid	OID of the parser's next-token function
prsend	regproc	pg_proc.oid	OID of the parser's shutdown function
prsheadline	regproc	pg_proc.oid	OID of the parser's headline function
prslextype	regproc	pg_proc.oid	OID of the parser's lextype function

48.51. pg_ts_template

The pg_ts_template catalog contains entries defining text search templates. A template is the implementation skeleton for a class of text search dictionaries. Since a template must be implemented by C-language-level functions, creation of new templates is restricted to database superusers.

PostgreSQL's text search features are described at length in Chapter 12.

Table 48-51. pg_ts_template Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
tmplname	name		Text search template name
tmplnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this template
tmplinit	regproc	pg_proc.oid	OID of the template's initialization function
tmpllexize	regproc	pg_proc.oid	OID of the template's lexize function

48.52. pg_type

The catalog pg_type stores information about data types. Base types and enum types (scalar types) are created with CREATE TYPE, and domains with CREATE DOMAIN. A composite type is automatically created for each table in the database, to represent the row structure of the table. It is also possible to create composite types with CREATE TYPE AS.

Table 48-52. pg_type Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
typname	name		Data type name
typnamespace	oid	pg_namespace.oid	The OID of the namespace that contains this type
typowner	oid	pg_authid.oid	Owner of the type

Name	Type	References	Description
typlen	int2		For a fixed-size type, typlen is the number of bytes in the internal representation of the type. But for a variable-length type, typlen is negative. -1 indicates a "varlena" type (one that has a length word), -2 indicates a null-terminated C string.
typbyval	bool		typbyval determines whether internal routines pass a value of this type by value or by reference. typbyval had better be false if typlen is not 1, 2, or 4 (or 8 on machines where Datum is 8 bytes). Variable-length types are always passed by reference. Note that typbyval can be false even if the length would allow pass-by-value.
typtype	char		typtype is b for a base type, c for a composite type (e.g., a table's row type), d for a domain, e for an enum type, p for a pseudo-type, or r for a range type. See also typrelid and typbasetype.
typcategory	char		typcategory is an arbitrary classification of data types that is used by the parser to determine which implicit casts should be "preferred". See Table 48-53.

Name	Type	References	Description
typispreferred	bool		True if the type is a preferred cast target within its typcategory
typisdefined	bool		True if the type is defined, false if this is a placeholder entry for a not-yet-defined type. When typisdefined is false, nothing except the type name, namespace, and OID can be relied on.
typdelim	char		Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type.
typrelid	oid	pg_class.oid	If this is a composite type (see typtype), then this column points to the pg_class entry that defines the corresponding table. (For a free-standing composite type, the pg_class entry doesn't really represent a table, but it is needed anyway for the type's pg_attribute entries to link to.) Zero for non-composite types.

Name	Type	References	Description
typelem	oid	pg_type.oid	If typelem is not 0 then it identifies another row in pg_type. The current type can then be subscripted like an array yielding values of type typelem. A "true" array type is variable length (typlen = -1), but some fixed-length (typlen > 0) types also have nonzero typelem, for example name and point. If a fixed-length type has a typelem then its internal representation must be some number of values of the typelem data type with no other data. Variable-length array types have a header defined by the array subroutines.
typarray	oid	pg_type.oid	If typarray is not 0 then it identifies another row in pg_type, which is the "true" array type having this type as element
typinput	regproc	pg_proc.oid	Input conversion function (text format)
typoutput	regproc	pg_proc.oid	Output conversion function (text format)
typreceive	regproc	pg_proc.oid	Input conversion function (binary format), or 0 if none
typsend	regproc	pg_proc.oid	Output conversion function (binary format), or 0 if none
typmodin	regproc	pg_proc.oid	Type modifier input function, or 0 if type does not support modifiers

Name	Type	References	Description
typmodout	regproc	pg_proc.oid	Type modifier output function, or 0 to use the standard format
typanalyze	regproc	pg_proc.oid	Custom ANALYZE function, or 0 to use the standard function

Name	Type	References	Description
typalign	char		typalign is the alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside PostgreSQL. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a datum of this type so that it begins on the specified boundary. The alignment reference is the beginning of the first datum in the sequence. Possible values are: • c = char alignment, i.e., no alignment needed. • s = short alignment (2 bytes on most machines). • i = int alignment (4 bytes on most machines). • d = double alignment (8 bytes on many machines, but by no means all). **Note:** For types used in system tables, it is critical that the size and alignment defined in pg_type agree with the way that the compiler will lay out the column in a structure representing a table row.

Name	Type	References	Description
typstorage	char		typstorage tells for varlena types (those with typlen = -1) if the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are • p: Value must always be stored plain. • e: Value can be stored in a "secondary" relation (if relation has one, see pg_class.reltoastrelid). • m: Value can be stored compressed inline. • x: Value can be stored compressed inline or stored in "secondary" storage. Note that m columns can also be moved out to secondary storage, but only as a last resort (e and x columns are moved first).
typnotnull	bool		typnotnull represents a not-null constraint on a type. Used for domains only.
typbasetype	oid	pg_type.oid	If this is a domain (see typtype), then typbasetype identifies the type that this one is based on. Zero if this type is not a domain.

Name	Type	References	Description
typtypmod	int4		Domains use typtypmod to record the typmod to be applied to their base type (-1 if base type does not use a typmod). -1 if this type is not a domain.
typndims	int4		typndims is the number of array dimensions for a domain over an array (that is, typbasetype is an array type). Zero for types other than domains over array types.
typcollation	oid	pg_collation.oid	typcollation specifies the collation of the type. If the type does not support collations, this will be zero. A base type that supports collations will have DEFAULT_COLLATION_OID here. A domain over a collatable type can have some other collation OID, if one was specified for the domain.
typdefaultbin	pg_node_tree		If typdefaultbin is not null, it is the nodeToString() representation of a default expression for the type. This is only used for domains.

Name	Type	References	Description
typdefault	text		typdefault is null if the type has no associated default value. If typdefaultbin is not null, typdefault must contain a human-readable version of the default expression represented by typdefaultbin. If typdefaultbin is null and typdefault is not, then typdefault is the external representation of the type's default value, which can be fed to the type's input converter to produce a constant.
typacl	aclitem[]		Access privileges; see GRANT and REVOKE for details

Table 48-53 lists the system-defined values of typcategory. Any future additions to this list will also be upper-case ASCII letters. All other ASCII characters are reserved for user-defined categories.

Table 48-53. typcategory Codes

Code	Category
A	Array types
B	Boolean types
C	Composite types
D	Date/time types
E	Enum types
G	Geometric types
I	Network address types
N	Numeric types
P	Pseudo-types
R	Range types
S	String types
T	Timespan types
U	User-defined types
V	Bit-string types
X	unknown type

48.53. pg_user_mapping

The catalog pg_user_mapping stores the mappings from local user to remote. Access to this catalog is restricted from normal users, use the view pg_user_mappings instead.

Table 48-54. pg_user_mapping Columns

Name	Type	References	Description
oid	oid		Row identifier (hidden attribute; must be explicitly selected)
umuser	oid	pg_authid.oid	OID of the local role being mapped, 0 if the user mapping is public
umserver	oid	pg_foreign_server.oid	The OID of the foreign server that contains this mapping
umoptions	text[]		User mapping specific options, as "keyword=value" strings

48.54. System Views

In addition to the system catalogs, PostgreSQL provides a number of built-in views. Some system views provide convenient access to some commonly used queries on the system catalogs. Other views provide access to internal server state.

The information schema (Chapter 34) provides an alternative set of views which overlap the functionality of the system views. Since the information schema is SQL-standard whereas the views described here are PostgreSQL-specific, it's usually better to use the information schema if it provides all the information you need.

Table 48-55 lists the system views described here. More detailed documentation of each view follows below. There are some additional views that provide access to the results of the statistics collector; they are described in Table 27-1.

Except where noted, all the views described here are read-only.

Table 48-55. System Views

View Name	Purpose
pg_available_extensions	available extensions
pg_available_extension_versions	available versions of extensions
pg_cursors	open cursors
pg_group	groups of database users
pg_indexes	indexes
pg_locks	currently held locks
pg_matviews	materialized views

View Name	Purpose
pg_prepared_statements	prepared statements
pg_prepared_xacts	prepared transactions
pg_roles	database roles
pg_rules	rules
pg_seclabels	security labels
pg_settings	parameter settings
pg_shadow	database users
pg_stats	planner statistics
pg_tables	tables
pg_timezone_abbrevs	time zone abbreviations
pg_timezone_names	time zone names
pg_user	database users
pg_user_mappings	user mappings
pg_views	views

48.55. pg_available_extensions

The pg_available_extensions view lists the extensions that are available for installation. See also the pg_extension catalog, which shows the extensions currently installed.

Table 48-56. pg_available_extensions Columns

Name	Type	Description
name	name	Extension name
default_version	text	Name of default version, or NULL if none is specified
installed_version	text	Currently installed version of the extension, or NULL if not installed
comment	text	Comment string from the extension's control file

The pg_available_extensions view is read only.

48.56. pg_available_extension_versions

The pg_available_extension_versions view lists the specific extension versions that are available for installation. See also the pg_extension catalog, which shows the extensions currently installed.

Table 48-57. pg_available_extension_versions Columns

Name	Type	Description

Name	Type	Description
name	name	Extension name
version	text	Version name
installed	bool	True if this version of this extension is currently installed
superuser	bool	True if only superusers are allowed to install this extension
relocatable	bool	True if extension can be relocated to another schema
schema	name	Name of the schema that the extension must be installed into, or NULL if partially or fully relocatable
requires	name[]	Names of prerequisite extensions, or NULL if none
comment	text	Comment string from the extension's control file

The pg_available_extension_versions view is read only.

48.57. pg_cursors

The pg_cursors view lists the cursors that are currently available. Cursors can be defined in several ways:

- via the DECLARE statement in SQL
- via the Bind message in the frontend/backend protocol, as described in Section 49.2.3
- via the Server Programming Interface (SPI), as described in Section 44.1

The pg_cursors view displays cursors created by any of these means. Cursors only exist for the duration of the transaction that defines them, unless they have been declared WITH HOLD. Therefore non-holdable cursors are only present in the view until the end of their creating transaction.

> **Note:** Cursors are used internally to implement some of the components of PostgreSQL, such as procedural languages. Therefore, the pg_cursors view might include cursors that have not been explicitly created by the user.

Table 48-58. pg_cursors Columns

Name	Type	Description
name	text	The name of the cursor
statement	text	The verbatim query string submitted to declare this cursor

Name	Type	Description
is_holdable	boolean	true if the cursor is holdable (that is, it can be accessed after the transaction that declared the cursor has committed); false otherwise
is_binary	boolean	true if the cursor was declared BINARY; false otherwise
is_scrollable	boolean	true if the cursor is scrollable (that is, it allows rows to be retrieved in a nonsequential manner); false otherwise
creation_time	timestamptz	The time at which the cursor was declared

The pg_cursors view is read only.

48.58. pg_group

The view pg_group exists for backwards compatibility: it emulates a catalog that existed in PostgreSQL before version 8.1. It shows the names and members of all roles that are marked as not rolcanlogin, which is an approximation to the set of roles that are being used as groups.

Table 48-59. pg_group Columns

Name	Type	References	Description
groname	name	pg_authid.rolname	Name of the group
grosysid	oid	pg_authid.oid	ID of this group
grolist	oid[]	pg_authid.oid	An array containing the IDs of the roles in this group

48.59. pg_indexes

The view pg_indexes provides access to useful information about each index in the database.

Table 48-60. pg_indexes Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table and index
tablename	name	pg_class.relname	Name of table the index is for
indexname	name	pg_class.relname	Name of index

Name	Type	References	Description
tablespace	name	pg_tablespace.spcname	Name of tablespace containing index (null if default for database)
indexdef	text		Index definition (a reconstructed CREATE INDEX command)

48.60. pg_locks

The view pg_locks provides access to information about the locks held by open transactions within the database server. See Chapter 13 for more discussion of locking.

pg_locks contains one row per active lockable object, requested lock mode, and relevant transaction. Thus, the same lockable object might appear many times, if multiple transactions are holding or waiting for locks on it. However, an object that currently has no locks on it will not appear at all.

There are several distinct types of lockable objects: whole relations (e.g., tables), individual pages of relations, individual tuples of relations, transaction IDs (both virtual and permanent IDs), and general database objects (identified by class OID and object OID, in the same way as in pg_description or pg_depend). Also, the right to extend a relation is represented as a separate lockable object. Also, "advisory" locks can be taken on numbers that have user-defined meanings.

Table 48-61. pg_locks Columns

Name	Type	References	Description
locktype	text		Type of the lockable object: relation, extend, page, tuple, transactionid, virtualxid, object, userlock, or advisory
database	oid	pg_database.oid	OID of the database in which the lock target exists, or zero if the target is a shared object, or null if the target is a transaction ID
relation	oid	pg_class.oid	OID of the relation targeted by the lock, or null if the target is not a relation or part of a relation

Name	Type	References	Description
page	integer		Page number targeted by the lock within the relation, or null if the target is not a relation page or tuple
tuple	smallint		Tuple number targeted by the lock within the page, or null if the target is not a tuple
virtualxid	text		Virtual ID of the transaction targeted by the lock, or null if the target is not a virtual transaction ID
transactionid	xid		ID of the transaction targeted by the lock, or null if the target is not a transaction ID
classid	oid	pg_class.oid	OID of the system catalog containing the lock target, or null if the target is not a general database object
objid	oid	any OID column	OID of the lock target within its system catalog, or null if the target is not a general database object
objsubid	smallint		Column number targeted by the lock (the classid and objid refer to the table itself), or zero if the target is some other general database object, or null if the target is not a general database object
virtualtransaction	text		Virtual ID of the transaction that is holding or awaiting this lock

Name	Type	References	Description
pid	integer		Process ID of the server process holding or awaiting this lock, or null if the lock is held by a prepared transaction
mode	text		Name of the lock mode held or desired by this process (see Section 13.3.1 and Section 13.2.3)
granted	boolean		True if lock is held, false if lock is awaited
fastpath	boolean		True if lock was taken via fast path, false if taken via main lock table

granted is true in a row representing a lock held by the indicated transaction. False indicates that this transaction is currently waiting to acquire this lock, which implies that some other transaction is holding a conflicting lock mode on the same lockable object. The waiting transaction will sleep until the other lock is released (or a deadlock situation is detected). A single transaction can be waiting to acquire at most one lock at a time.

Every transaction holds an exclusive lock on its virtual transaction ID for its entire duration. If a permanent ID is assigned to the transaction (which normally happens only if the transaction changes the state of the database), it also holds an exclusive lock on its permanent transaction ID until it ends. When one transaction finds it necessary to wait specifically for another transaction, it does so by attempting to acquire share lock on the other transaction ID (either virtual or permanent ID depending on the situation). That will succeed only when the other transaction terminates and releases its locks.

Although tuples are a lockable type of object, information about row-level locks is stored on disk, not in memory, and therefore row-level locks normally do not appear in this view. If a transaction is waiting for a row-level lock, it will usually appear in the view as waiting for the permanent transaction ID of the current holder of that row lock.

Advisory locks can be acquired on keys consisting of either a single bigint value or two integer values. A bigint key is displayed with its high-order half in the classid column, its low-order half in the objid column, and objsubid equal to 1. The original bigint value can be reassembled with the expression (classid::bigint << 32) | objid::bigint. Integer keys are displayed with the first key in the classid column, the second key in the objid column, and objsubid equal to 2. The actual meaning of the keys is up to the user. Advisory locks are local to each database, so the database column is meaningful for an advisory lock.

pg_locks provides a global view of all locks in the database cluster, not only those relevant to the current database. Although its relation column can be joined against pg_class.oid to identify locked relations, this will only work correctly for relations in the current database (those for which the database column is either the current database's OID or zero).

The pid column can be joined to the pid column of the pg_stat_activity view to get more information on the session holding or waiting to hold each lock, for example

```
SELECT * FROM pg_locks pl LEFT JOIN pg_stat_activity psa
```

```
    ON pl.pid = psa.pid;
```

Also, if you are using prepared transactions, the `virtualtransaction` column can be joined to the `transaction` column of the `pg_prepared_xacts` view to get more information on prepared transactions that hold locks. (A prepared transaction can never be waiting for a lock, but it continues to hold the locks it acquired while running.) For example:

```
SELECT * FROM pg_locks pl LEFT JOIN pg_prepared_xacts ppx
    ON pl.virtualtransaction = '-1/' || ppx.transaction;
```

The `pg_locks` view displays data from both the regular lock manager and the predicate lock manager, which are separate systems; in addition, the regular lock manager subdivides its locks into regular and *fast-path* locks. This data is not guaranteed to be entirely consistent. When the view is queried, data on fast-path locks (with `fastpath` = `true`) is gathered from each backend one at a time, without freezing the state of the entire lock manager, so it is possible for locks to be taken or released while information is gathered. Note, however, that these locks are known not to conflict with any other lock currently in place. After all backends have been queried for fast-path locks, the remainder of the regular lock manager is locked as a unit, and a consistent snapshot of all remaining locks is collected as an atomic action. After unlocking the regular lock manager, the predicate lock manager is similarly locked and all predicate locks are collected as an atomic action. Thus, with the exception of fast-path locks, each lock manager will deliver a consistent set of results, but as we do not lock both lock managers simultaneously, it is possible for locks to be taken or released after we interrogate the regular lock manager and before we interrogate the predicate lock manager.

Locking the regular and/or predicate lock manager could have some impact on database performance if this view is very frequently accessed. The locks are held only for the minimum amount of time necessary to obtain data from the lock managers, but this does not completely eliminate the possibility of a performance impact.

48.61. `pg_matviews`

The view `pg_matviews` provides access to useful information about each materialized view in the database.

Table 48-62. `pg_matviews` Columns

Name	Type	References	Description
`schemaname`	`name`	`pg_namespace.nspname`	Name of schema containing materialized view
`matviewname`	`name`	`pg_class.relname`	Name of materialized view
`matviewowner`	`name`	`pg_authid.rolname`	Name of materialized view's owner
`tablespace`	`name`	`pg_tablespace.spcname`	Name of tablespace containing materialized view (null if default for database)

Name	Type	References	Description
hasindexes	boolean		True if materialized view has (or recently had) any indexes
ispopulated	boolean		True if materialized view is currently populated
definition	text		Materialized view definition (a reconstructed SELECT query)

48.62. pg_prepared_statements

The pg_prepared_statements view displays all the prepared statements that are available in the current session. See PREPARE for more information about prepared statements.

pg_prepared_statements contains one row for each prepared statement. Rows are added to the view when a new prepared statement is created and removed when a prepared statement is released (for example, via the DEALLOCATE command).

Table 48-63. pg_prepared_statements Columns

Name	Type	Description
name	text	The identifier of the prepared statement
statement	text	The query string submitted by the client to create this prepared statement. For prepared statements created via SQL, this is the PREPARE statement submitted by the client. For prepared statements created via the frontend/backend protocol, this is the text of the prepared statement itself.
prepare_time	timestamptz	The time at which the prepared statement was created
parameter_types	regtype[]	The expected parameter types for the prepared statement in the form of an array of regtype. The OID corresponding to an element of this array can be obtained by casting the regtype value to oid.

Name	Type	Description
from_sql	boolean	true if the prepared statement was created via the PREPARE SQL statement; false if the statement was prepared via the frontend/backend protocol

The pg_prepared_statements view is read only.

48.63. pg_prepared_xacts

The view pg_prepared_xacts displays information about transactions that are currently prepared for two-phase commit (see PREPARE TRANSACTION for details).

pg_prepared_xacts contains one row per prepared transaction. An entry is removed when the transaction is committed or rolled back.

Table 48-64. pg_prepared_xacts Columns

Name	Type	References	Description
transaction	xid		Numeric transaction identifier of the prepared transaction
gid	text		Global transaction identifier that was assigned to the transaction
prepared	timestamp with time zone		Time at which the transaction was prepared for commit
owner	name	pg_authid.rolname	Name of the user that executed the transaction
database	name	pg_database.datname	Name of the database in which the transaction was executed

When the pg_prepared_xacts view is accessed, the internal transaction manager data structures are momentarily locked, and a copy is made for the view to display. This ensures that the view produces a consistent set of results, while not blocking normal operations longer than necessary. Nonetheless there could be some impact on database performance if this view is frequently accessed.

48.64. pg_roles

The view pg_roles provides access to information about database roles. This is simply a publicly readable view of pg_authid that blanks out the password field.

This view explicitly exposes the OID column of the underlying table, since that is needed to do joins

to other catalogs.

Table 48-65. `pg_roles` Columns

Name	Type	References	Description
`rolname`	`name`		Role name
`rolsuper`	`bool`		Role has superuser privileges
`rolinherit`	`bool`		Role automatically inherits privileges of roles it is a member of
`rolcreaterole`	`bool`		Role can create more roles
`rolcreatedb`	`bool`		Role can create databases
`rolcatupdate`	`bool`		Role can update system catalogs directly. (Even a superuser cannot do this unless this column is true)
`rolcanlogin`	`bool`		Role can log in. That is, this role can be given as the initial session authorization identifier
`rolreplication`	`bool`		Role is a replication role. That is, this role can initiate streaming replication (see Section 25.2.5) and set/unset the system backup mode using `pg_start_backup` and `pg_stop_backup`
`rolconnlimit`	`int4`		For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit.
`rolpassword`	`text`		Not the password (always reads as `********`)

Name	Type	References	Description
rolvaliduntil	timestamptz		Password expiry time (only used for password authentication); null if no expiration
rolconfig	text[]		Role-specific defaults for run-time configuration variables
oid	oid	pg_authid.oid	ID of role

48.65. pg_rules

The view pg_rules provides access to useful information about query rewrite rules.

Table 48-66. pg_rules Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table the rule is for
rulename	name	pg_rewrite.rulename	Name of rule
definition	text		Rule definition (a reconstructed creation command)

The pg_rules view excludes the ON SELECT rules of views and materialized views; those can be seen in pg_views and pg_matviews.

48.66. pg_seclabels

The view pg_seclabels provides information about security labels. It as an easier-to-query version of the pg_seclabel catalog.

Table 48-67. pg_seclabels Columns

Name	Type	References	Description
objoid	oid	any OID column	The OID of the object this security label pertains to
classoid	oid	pg_class.oid	The OID of the system catalog this object appears in

Name	Type	References	Description
objsubid	int4		For a security label on a table column, this is the column number (the objoid and classoid refer to the table itself). For all other object types, this column is zero.
objtype	text		The type of object to which this label applies, as text.
objnamespace	oid	pg_namespace.oid	The OID of the namespace for this object, if applicable; otherwise NULL.
objname	text		The name of the object to which this label applies, as text.
provider	text	pg_seclabel.provider	The label provider associated with this label.
label	text	pg_seclabel.label	The security label applied to this object.

48.67. pg_settings

The view pg_settings provides access to run-time parameters of the server. It is essentially an alternative interface to the SHOW and SET commands. It also provides access to some facts about each parameter that are not directly available from SHOW, such as minimum and maximum values.

Table 48-68. pg_settings Columns

Name	Type	Description
name	text	Run-time configuration parameter name
setting	text	Current value of the parameter
unit	text	Implicit unit of the parameter
category	text	Logical group of the parameter
short_desc	text	A brief description of the parameter
extra_desc	text	Additional, more detailed, description of the parameter
context	text	Context required to set the parameter's value (see below)

Name	Type	Description
vartype	text	Parameter type (bool, enum, integer, real, or string)
source	text	Source of the current parameter value
min_val	text	Minimum allowed value of the parameter (null for non-numeric values)
max_val	text	Maximum allowed value of the parameter (null for non-numeric values)
enumvals	text[]	Allowed values of an enum parameter (null for non-enum values)
boot_val	text	Parameter value assumed at server startup if the parameter is not otherwise set
reset_val	text	Value that RESET would reset the parameter to in the current session
sourcefile	text	Configuration file the current value was set in (null for values set from sources other than configuration files, or when examined by a non-superuser); helpful when using include directives in configuration files
sourceline	integer	Line number within the configuration file the current value was set at (null for values set from sources other than configuration files, or when examined by a non-superuser)

There are several possible values of context. In order of decreasing difficulty of changing the setting, they are:

internal

These settings cannot be changed directly; they reflect internally determined values. Some of them may be adjustable by rebuilding the server with different configuration options, or by changing options supplied to initdb.

postmaster

These settings can only be applied when the server starts, so any change requires restarting the server. Values for these settings are typically stored in the postgresql.conf file, or passed on the command line when starting the server. Of course, settings with any of the lower context types can also be set at server start time.

sighup

Changes to these settings can be made in postgresql.conf without restarting the server. Send

a SIGHUP signal to the postmaster to cause it to re-read postgresql.conf and apply the changes. The postmaster will also forward the SIGHUP signal to its child processes so that they all pick up the new value.

backend

Changes to these settings can be made in postgresql.conf without restarting the server; they can also be set for a particular session in the connection request packet (for example, via libpq's PGOPTIONS environment variable). However, these settings never change in a session after it is started. If you change them in postgresql.conf, send a SIGHUP signal to the postmaster to cause it to re-read postgresql.conf. The new values will only affect subsequently-launched sessions.

superuser

These settings can be set from postgresql.conf, or within a session via the SET command; but only superusers can change them via SET. Changes in postgresql.conf will affect existing sessions only if no session-local value has been established with SET.

user

These settings can be set from postgresql.conf, or within a session via the SET command. Any user is allowed to change his session-local value. Changes in postgresql.conf will affect existing sessions only if no session-local value has been established with SET.

See Section 18.1 for more information about the various ways to change these parameters.

The pg_settings view cannot be inserted into or deleted from, but it can be updated. An UPDATE applied to a row of pg_settings is equivalent to executing the SET command on that named parameter. The change only affects the value used by the current session. If an UPDATE is issued within a transaction that is later aborted, the effects of the UPDATE command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another UPDATE or SET.

48.68. pg_shadow

The view pg_shadow exists for backwards compatibility: it emulates a catalog that existed in PostgreSQL before version 8.1. It shows properties of all roles that are marked as rolcanlogin in pg_authid.

The name stems from the fact that this table should not be readable by the public since it contains passwords. pg_user is a publicly readable view on pg_shadow that blanks out the password field.

Table 48-69. pg_shadow Columns

Name	Type	References	Description
usename	name	pg_authid.rolname	User name
usesysid	oid	pg_authid.oid	ID of this user
usecreatedb	bool		User can create databases
usesuper	bool		User is a superuser

Name	Type	References	Description
usecatupd	bool		User can update system catalogs. (Even a superuser cannot do this unless this column is true.)
userepl	bool		User can initiate streaming replication and put the system in and out of backup mode.
passwd	text		Password (possibly encrypted); null if none. See pg_authid for details of how encrypted passwords are stored.
valuntil	abstime		Password expiry time (only used for password authentication)
useconfig	text[]		Session defaults for run-time configuration variables

48.69. pg_stats

The view pg_stats provides access to the information stored in the pg_statistic catalog. This view allows access only to rows of pg_statistic that correspond to tables the user has permission to read, and therefore it is safe to allow public read access to this view.

pg_stats is also designed to present the information in a more readable format than the underlying catalog — at the cost that its schema must be extended whenever new slot types are defined for pg_statistic.

Table 48-70. pg_stats Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table
attname	name	pg_attribute.attname	Name of the column described by this row
inherited	bool		If true, this row includes inheritance child columns, not just the values in the specified table

Name	Type	References	Description
null_frac	real		Fraction of column entries that are null
avg_width	integer		Average width in bytes of column's entries
n_distinct	real		If greater than zero, the estimated number of distinct values in the column. If less than zero, the negative of the number of distinct values divided by the number of rows. (The negated form is used when ANALYZE believes that the number of distinct values is likely to increase as the table grows; the positive form is used when the column seems to have a fixed number of possible values.) For example, -1 indicates a unique column in which the number of distinct values is the same as the number of rows.
most_common_vals	anyarray		A list of the most common values in the column. (Null if no values seem to be more common than any others.)
most_common_freqs	real[]		A list of the frequencies of the most common values, i.e., number of occurrences of each divided by total number of rows. (Null when most_common_vals is.)

Name	Type	References	Description
histogram_bounds	anyarray		A list of values that divide the column's values into groups of approximately equal population. The values in most_common_vals, if present, are omitted from this histogram calculation. (This column is null if the column data type does not have a < operator or if the most_common_vals list accounts for the entire population.)
correlation	real		Statistical correlation between physical row ordering and logical ordering of the column values. This ranges from -1 to +1. When the value is near -1 or +1, an index scan on the column will be estimated to be cheaper than when it is near zero, due to reduction of random access to the disk. (This column is null if the column data type does not have a < operator.)
most_common_elems	anyarray		A list of non-null element values most often appearing within values of the column. (Null for scalar types.)

Name	Type	References	Description
most_common_elem_freqs	real[]		A list of the frequencies of the most common element values, i.e., the fraction of rows containing at least one instance of the given value. Two or three additional values follow the per-element frequencies; these are the minimum and maximum of the preceding per-element frequencies, and optionally the frequency of null elements. (Null when most_common_elems is.)
elem_count_histogram	real[]		A histogram of the counts of distinct non-null element values within the values of the column, followed by the average number of distinct non-null elements. (Null for scalar types.)

The maximum number of entries in the array fields can be controlled on a column-by-column basis using the ALTER TABLE SET STATISTICS command, or globally by setting the default_statistics_target run-time parameter.

48.70. pg_tables

The view pg_tables provides access to useful information about each table in the database.

Table 48-71. pg_tables Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing table
tablename	name	pg_class.relname	Name of table
tableowner	name	pg_authid.rolname	Name of table's owner
tablespace	name	pg_tablespace.spcname	Name of tablespace containing table (null if default for database)

Name	Type	References	Description
hasindexes	boolean	pg_class.relhasindex	True if table has (or recently had) any indexes
hasrules	boolean	pg_class.relhasrules	True if table has (or once had) rules
hastriggers	boolean	pg_class.relhastriggers	True if table has (or once had) triggers

48.71. pg_timezone_abbrevs

The view pg_timezone_abbrevs provides a list of time zone abbreviations that are currently recognized by the datetime input routines. The contents of this view change when the timezone_abbreviations run-time parameter is modified.

Table 48-72. pg_timezone_abbrevs Columns

Name	Type	Description
abbrev	text	Time zone abbreviation
utc_offset	interval	Offset from UTC (positive means east of Greenwich)
is_dst	boolean	True if this is a daylight-savings abbreviation

48.72. pg_timezone_names

The view pg_timezone_names provides a list of time zone names that are recognized by SET TIMEZONE, along with their associated abbreviations, UTC offsets, and daylight-savings status. (Technically, PostgreSQL uses UT1 rather than UTC because leap seconds are not handled.) Unlike the abbreviations shown in pg_timezone_abbrevs, many of these names imply a set of daylight-savings transition date rules. Therefore, the associated information changes across local DST boundaries. The displayed information is computed based on the current value of CURRENT_TIMESTAMP.

Table 48-73. pg_timezone_names Columns

Name	Type	Description
name	text	Time zone name
abbrev	text	Time zone abbreviation
utc_offset	interval	Offset from UTC (positive means east of Greenwich)
is_dst	boolean	True if currently observing daylight savings

48.73. pg_user

The view pg_user provides access to information about database users. This is simply a publicly readable view of pg_shadow that blanks out the password field.

Table 48-74. pg_user Columns

Name	Type	Description
usename	name	User name
usesysid	oid	ID of this user
usecreatedb	bool	User can create databases
usesuper	bool	User is a superuser
usecatupd	bool	User can update system catalogs. (Even a superuser cannot do this unless this column is true.)
userepl	bool	User can initiate streaming replication and put the system in and out of backup mode.
passwd	text	Not the password (always reads as ********)
valuntil	abstime	Password expiry time (only used for password authentication)
useconfig	text[]	Session defaults for run-time configuration variables

48.74. pg_user_mappings

The view pg_user_mappings provides access to information about user mappings. This is essentially a publicly readable view of pg_user_mapping that leaves out the options field if the user has no rights to use it.

Table 48-75. pg_user_mappings Columns

Name	Type	References	Description
umid	oid	pg_user_mapping.oid	OID of the user mapping
srvid	oid	pg_foreign_server.oid	The OID of the foreign server that contains this mapping
srvname	name	pg_foreign_server.srvname	Name of the foreign server
umuser	oid	pg_authid.oid	OID of the local role being mapped, 0 if the user mapping is public

Name	Type	References	Description
usename	name		Name of the local user to be mapped
umoptions	text[]		User mapping specific options, as "keyword=value" strings, if the current user is the owner of the foreign server, else null

48.75. pg_views

The view pg_views provides access to useful information about each view in the database.

Table 48-76. pg_views Columns

Name	Type	References	Description
schemaname	name	pg_namespace.nspname	Name of schema containing view
viewname	name	pg_class.relname	Name of view
viewowner	name	pg_authid.rolname	Name of view's owner
definition	text		View definition (a reconstructed SELECT query)

Chapter 49. Frontend/Backend Protocol

PostgreSQL uses a message-based protocol for communication between frontends and backends (clients and servers). The protocol is supported over TCP/IP and also over Unix-domain sockets. Port number 5432 has been registered with IANA as the customary TCP port number for servers supporting this protocol, but in practice any non-privileged port number can be used.

This document describes version 3.0 of the protocol, implemented in PostgreSQL 7.4 and later. For descriptions of the earlier protocol versions, see previous releases of the PostgreSQL documentation. A single server can support multiple protocol versions. The initial startup-request message tells the server which protocol version the client is attempting to use, and then the server follows that protocol if it is able.

In order to serve multiple clients efficiently, the server launches a new "backend" process for each client. In the current implementation, a new child process is created immediately after an incoming connection is detected. This is transparent to the protocol, however. For purposes of the protocol, the terms "backend" and "server" are interchangeable; likewise "frontend" and "client" are interchangeable.

49.1. Overview

The protocol has separate phases for startup and normal operation. In the startup phase, the frontend opens a connection to the server and authenticates itself to the satisfaction of the server. (This might involve a single message, or multiple messages depending on the authentication method being used.) If all goes well, the server then sends status information to the frontend, and finally enters normal operation. Except for the initial startup-request message, this part of the protocol is driven by the server.

During normal operation, the frontend sends queries and other commands to the backend, and the backend sends back query results and other responses. There are a few cases (such as `NOTIFY`) wherein the backend will send unsolicited messages, but for the most part this portion of a session is driven by frontend requests.

Termination of the session is normally by frontend choice, but can be forced by the backend in certain cases. In any case, when the backend closes the connection, it will roll back any open (incomplete) transaction before exiting.

Within normal operation, SQL commands can be executed through either of two sub-protocols. In the "simple query" protocol, the frontend just sends a textual query string, which is parsed and immediately executed by the backend. In the "extended query" protocol, processing of queries is separated into multiple steps: parsing, binding of parameter values, and execution. This offers flexibility and performance benefits, at the cost of extra complexity.

Normal operation has additional sub-protocols for special operations such as `COPY`.

49.1.1. Messaging Overview

All communication is through a stream of messages. The first byte of a message identifies the message type, and the next four bytes specify the length of the rest of the message (this length count includes itself, but not the message-type byte). The remaining contents of the message are determined by the

message type. For historical reasons, the very first message sent by the client (the startup message) has no initial message-type byte.

To avoid losing synchronization with the message stream, both servers and clients typically read an entire message into a buffer (using the byte count) before attempting to process its contents. This allows easy recovery if an error is detected while processing the contents. In extreme situations (such as not having enough memory to buffer the message), the receiver can use the byte count to determine how much input to skip before it resumes reading messages.

Conversely, both servers and clients must take care never to send an incomplete message. This is commonly done by marshaling the entire message in a buffer before beginning to send it. If a communications failure occurs partway through sending or receiving a message, the only sensible response is to abandon the connection, since there is little hope of recovering message-boundary synchronization.

49.1.2. Extended Query Overview

In the extended-query protocol, execution of SQL commands is divided into multiple steps. The state retained between steps is represented by two types of objects: *prepared statements* and *portals*. A prepared statement represents the result of parsing and semantic analysis of a textual query string. A prepared statement is not in itself ready to execute, because it might lack specific values for *parameters*. A portal represents a ready-to-execute or already-partially-executed statement, with any missing parameter values filled in. (For `SELECT` statements, a portal is equivalent to an open cursor, but we choose to use a different term since cursors don't handle non-`SELECT` statements.)

The overall execution cycle consists of a *parse* step, which creates a prepared statement from a textual query string; a *bind* step, which creates a portal given a prepared statement and values for any needed parameters; and an *execute* step that runs a portal's query. In the case of a query that returns rows (`SELECT`, `SHOW`, etc), the execute step can be told to fetch only a limited number of rows, so that multiple execute steps might be needed to complete the operation.

The backend can keep track of multiple prepared statements and portals (but note that these exist only within a session, and are never shared across sessions). Existing prepared statements and portals are referenced by names assigned when they were created. In addition, an "unnamed" prepared statement and portal exist. Although these behave largely the same as named objects, operations on them are optimized for the case of executing a query only once and then discarding it, whereas operations on named objects are optimized on the expectation of multiple uses.

49.1.3. Formats and Format Codes

Data of a particular data type might be transmitted in any of several different *formats*. As of PostgreSQL 7.4 the only supported formats are "text" and "binary", but the protocol makes provision for future extensions. The desired format for any value is specified by a *format code*. Clients can specify a format code for each transmitted parameter value and for each column of a query result. Text has format code zero, binary has format code one, and all other format codes are reserved for future definition.

The text representation of values is whatever strings are produced and accepted by the input/output conversion functions for the particular data type. In the transmitted representation, there is no trailing null character; the frontend must add one to received values if it wants to process them as C strings. (The text format does not allow embedded nulls, by the way.)

Binary representations for integers use network byte order (most significant byte first). For other data types consult the documentation or source code to learn about the binary representation. Keep in

mind that binary representations for complex data types might change across server versions; the text format is usually the more portable choice.

49.2. Message Flow

This section describes the message flow and the semantics of each message type. (Details of the exact representation of each message appear in Section 49.5.) There are several different sub-protocols depending on the state of the connection: start-up, query, function call, `COPY`, and termination. There are also special provisions for asynchronous operations (including notification responses and command cancellation), which can occur at any time after the start-up phase.

49.2.1. Start-up

To begin a session, a frontend opens a connection to the server and sends a startup message. This message includes the names of the user and of the database the user wants to connect to; it also identifies the particular protocol version to be used. (Optionally, the startup message can include additional settings for run-time parameters.) The server then uses this information and the contents of its configuration files (such as `pg_hba.conf`) to determine whether the connection is provisionally acceptable, and what additional authentication is required (if any).

The server then sends an appropriate authentication request message, to which the frontend must reply with an appropriate authentication response message (such as a password). For all authentication methods except GSSAPI and SSPI, there is at most one request and one response. In some methods, no response at all is needed from the frontend, and so no authentication request occurs. For GSSAPI and SSPI, multiple exchanges of packets may be needed to complete the authentication.

The authentication cycle ends with the server either rejecting the connection attempt (ErrorResponse), or sending AuthenticationOk.

The possible messages from the server in this phase are:

ErrorResponse

The connection attempt has been rejected. The server then immediately closes the connection.

AuthenticationOk

The authentication exchange is successfully completed.

AuthenticationKerberosV5

The frontend must now take part in a Kerberos V5 authentication dialog (not described here, part of the Kerberos specification) with the server. If this is successful, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse. This is no longer supported.

AuthenticationCleartextPassword

The frontend must now send a PasswordMessage containing the password in clear-text form. If this is the correct password, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse.

AuthenticationMD5Password

The frontend must now send a PasswordMessage containing the password (with username) encrypted via MD5, then encrypted again using the 4-byte random salt specified in the AuthenticationMD5Password message. If this is the correct password, the server responds with

an AuthenticationOk, otherwise it responds with an ErrorResponse. The actual PasswordMessage can be computed in SQL as `concat('md5', md5(concat(md5(concat(password, username)), random-salt)))`. (Keep in mind the `md5()` function returns its result as a hex string.)

AuthenticationSCMCredential

This response is only possible for local Unix-domain connections on platforms that support SCM credential messages. The frontend must issue an SCM credential message and then send a single data byte. (The contents of the data byte are uninteresting; it's only used to ensure that the server waits long enough to receive the credential message.) If the credential is acceptable, the server responds with an AuthenticationOk, otherwise it responds with an ErrorResponse. (This message type is only issued by pre-9.1 servers. It may eventually be removed from the protocol specification.)

AuthenticationGSS

The frontend must now initiate a GSSAPI negotiation. The frontend will send a PasswordMessage with the first part of the GSSAPI data stream in response to this. If further messages are needed, the server will respond with AuthenticationGSSContinue.

AuthenticationSSPI

The frontend must now initiate a SSPI negotiation. The frontend will send a PasswordMessage with the first part of the SSPI data stream in response to this. If further messages are needed, the server will respond with AuthenticationGSSContinue.

AuthenticationGSSContinue

This message contains the response data from the previous step of GSSAPI or SSPI negotiation (AuthenticationGSS, AuthenticationSSPI or a previous AuthenticationGSSContinue). If the GSSAPI or SSPI data in this message indicates more data is needed to complete the authentication, the frontend must send that data as another PasswordMessage. If GSSAPI or SSPI authentication is completed by this message, the server will next send AuthenticationOk to indicate successful authentication or ErrorResponse to indicate failure.

If the frontend does not support the authentication method requested by the server, then it should immediately close the connection.

After having received AuthenticationOk, the frontend must wait for further messages from the server. In this phase a backend process is being started, and the frontend is just an interested bystander. It is still possible for the startup attempt to fail (ErrorResponse), but in the normal case the backend will send some ParameterStatus messages, BackendKeyData, and finally ReadyForQuery.

During this phase the backend will attempt to apply any additional run-time parameter settings that were given in the startup message. If successful, these values become session defaults. An error causes ErrorResponse and exit.

The possible messages from the backend in this phase are:

BackendKeyData

This message provides secret-key data that the frontend must save if it wants to be able to issue cancel requests later. The frontend should not respond to this message, but should continue listening for a ReadyForQuery message.

ParameterStatus

This message informs the frontend about the current (initial) setting of backend parameters, such as client_encoding or DateStyle. The frontend can ignore this message, or record the settings

for its future use; see Section 49.2.6 for more details. The frontend should not respond to this message, but should continue listening for a ReadyForQuery message.

ReadyForQuery

Start-up is completed. The frontend can now issue commands.

ErrorResponse

Start-up failed. The connection is closed after sending this message.

NoticeResponse

A warning message has been issued. The frontend should display the message but continue listening for ReadyForQuery or ErrorResponse.

The ReadyForQuery message is the same one that the backend will issue after each command cycle. Depending on the coding needs of the frontend, it is reasonable to consider ReadyForQuery as starting a command cycle, or to consider ReadyForQuery as ending the start-up phase and each subsequent command cycle.

49.2.2. Simple Query

A simple query cycle is initiated by the frontend sending a Query message to the backend. The message includes an SQL command (or commands) expressed as a text string. The backend then sends one or more response messages depending on the contents of the query command string, and finally a ReadyForQuery response message. ReadyForQuery informs the frontend that it can safely send a new command. (It is not actually necessary for the frontend to wait for ReadyForQuery before issuing another command, but the frontend must then take responsibility for figuring out what happens if the earlier command fails and already-issued later commands succeed.)

The possible response messages from the backend are:

CommandComplete

An SQL command completed normally.

CopyInResponse

The backend is ready to copy data from the frontend to a table; see Section 49.2.5.

CopyOutResponse

The backend is ready to copy data from a table to the frontend; see Section 49.2.5.

RowDescription

Indicates that rows are about to be returned in response to a `SELECT`, `FETCH`, etc query. The contents of this message describe the column layout of the rows. This will be followed by a DataRow message for each row being returned to the frontend.

DataRow

One of the set of rows returned by a `SELECT`, `FETCH`, etc query.

EmptyQueryResponse

An empty query string was recognized.

ErrorResponse

An error has occurred.

ReadyForQuery

Processing of the query string is complete. A separate message is sent to indicate this because the query string might contain multiple SQL commands. (CommandComplete marks the end of processing one SQL command, not the whole string.) ReadyForQuery will always be sent, whether processing terminates successfully or with an error.

NoticeResponse

A warning message has been issued in relation to the query. Notices are in addition to other responses, i.e., the backend will continue processing the command.

The response to a `SELECT` query (or other queries that return row sets, such as `EXPLAIN` or `SHOW`) normally consists of RowDescription, zero or more DataRow messages, and then CommandComplete. `COPY` to or from the frontend invokes special protocol as described in Section 49.2.5. All other query types normally produce only a CommandComplete message.

Since a query string could contain several queries (separated by semicolons), there might be several such response sequences before the backend finishes processing the query string. ReadyForQuery is issued when the entire string has been processed and the backend is ready to accept a new query string.

If a completely empty (no contents other than whitespace) query string is received, the response is EmptyQueryResponse followed by ReadyForQuery.

In the event of an error, ErrorResponse is issued followed by ReadyForQuery. All further processing of the query string is aborted by ErrorResponse (even if more queries remained in it). Note that this might occur partway through the sequence of messages generated by an individual query.

In simple Query mode, the format of retrieved values is always text, except when the given command is a `FETCH` from a cursor declared with the `BINARY` option. In that case, the retrieved values are in binary format. The format codes given in the RowDescription message tell which format is being used.

A frontend must be prepared to accept ErrorResponse and NoticeResponse messages whenever it is expecting any other type of message. See also Section 49.2.6 concerning messages that the backend might generate due to outside events.

Recommended practice is to code frontends in a state-machine style that will accept any message type at any time that it could make sense, rather than wiring in assumptions about the exact sequence of messages.

49.2.3. Extended Query

The extended query protocol breaks down the above-described simple query protocol into multiple steps. The results of preparatory steps can be re-used multiple times for improved efficiency. Furthermore, additional features are available, such as the possibility of supplying data values as separate parameters instead of having to insert them directly into a query string.

In the extended protocol, the frontend first sends a Parse message, which contains a textual query string, optionally some information about data types of parameter placeholders, and the name of a destination prepared-statement object (an empty string selects the unnamed prepared statement). The response is either ParseComplete or ErrorResponse. Parameter data types can be specified by OID; if not given, the parser attempts to infer the data types in the same way as it would do for untyped literal string constants.

Note: A parameter data type can be left unspecified by setting it to zero, or by making the array of parameter type OIDs shorter than the number of parameter symbols (`$n`) used in the query string. Another special case is that a parameter's type can be specified as `void` (that is, the OID of the `void` pseudotype). This is meant to allow parameter symbols to be used for function parameters that are actually OUT parameters. Ordinarily there is no context in which a `void` parameter could be used, but if such a parameter symbol appears in a function's parameter list, it is effectively ignored. For example, a function call such as `foo($1,$2,$3,$4)` could match a function with two IN and two OUT arguments, if `$3` and `$4` are specified as having type `void`.

Note: The query string contained in a Parse message cannot include more than one SQL statement; else a syntax error is reported. This restriction does not exist in the simple-query protocol, but it does exist in the extended protocol, because allowing prepared statements or portals to contain multiple commands would complicate the protocol unduly.

If successfully created, a named prepared-statement object lasts till the end of the current session, unless explicitly destroyed. An unnamed prepared statement lasts only until the next Parse statement specifying the unnamed statement as destination is issued. (Note that a simple Query message also destroys the unnamed statement.) Named prepared statements must be explicitly closed before they can be redefined by another Parse message, but this is not required for the unnamed statement. Named prepared statements can also be created and accessed at the SQL command level, using `PREPARE` and `EXECUTE`.

Once a prepared statement exists, it can be readied for execution using a Bind message. The Bind message gives the name of the source prepared statement (empty string denotes the unnamed prepared statement), the name of the destination portal (empty string denotes the unnamed portal), and the values to use for any parameter placeholders present in the prepared statement. The supplied parameter set must match those needed by the prepared statement. (If you declared any `void` parameters in the Parse message, pass NULL values for them in the Bind message.) Bind also specifies the format to use for any data returned by the query; the format can be specified overall, or per-column. The response is either BindComplete or ErrorResponse.

Note: The choice between text and binary output is determined by the format codes given in Bind, regardless of the SQL command involved. The `BINARY` attribute in cursor declarations is irrelevant when using extended query protocol.

Query planning typically occurs when the Bind message is processed. If the prepared statement has no parameters, or is executed repeatedly, the server might save the created plan and re-use it during subsequent Bind messages for the same prepared statement. However, it will do so only if it finds that a generic plan can be created that is not much less efficient than a plan that depends on the specific parameter values supplied. This happens transparently so far as the protocol is concerned.

If successfully created, a named portal object lasts till the end of the current transaction, unless explicitly destroyed. An unnamed portal is destroyed at the end of the transaction, or as soon as the next Bind statement specifying the unnamed portal as destination is issued. (Note that a simple Query message also destroys the unnamed portal.) Named portals must be explicitly closed before they can be redefined by another Bind message, but this is not required for the unnamed portal. Named portals can also be created and accessed at the SQL command level, using `DECLARE CURSOR` and `FETCH`.

Once a portal exists, it can be executed using an Execute message. The Execute message specifies the portal name (empty string denotes the unnamed portal) and a maximum result-row count (zero meaning "fetch all rows"). The result-row count is only meaningful for portals containing commands

that return row sets; in other cases the command is always executed to completion, and the row count is ignored. The possible responses to Execute are the same as those described above for queries issued via simple query protocol, except that Execute doesn't cause ReadyForQuery or RowDescription to be issued.

If Execute terminates before completing the execution of a portal (due to reaching a nonzero result-row count), it will send a PortalSuspended message; the appearance of this message tells the frontend that another Execute should be issued against the same portal to complete the operation. The CommandComplete message indicating completion of the source SQL command is not sent until the portal's execution is completed. Therefore, an Execute phase is always terminated by the appearance of exactly one of these messages: CommandComplete, EmptyQueryResponse (if the portal was created from an empty query string), ErrorResponse, or PortalSuspended.

At completion of each series of extended-query messages, the frontend should issue a Sync message. This parameterless message causes the backend to close the current transaction if it's not inside a `BEGIN`/`COMMIT` transaction block ("close" meaning to commit if no error, or roll back if error). Then a ReadyForQuery response is issued. The purpose of Sync is to provide a resynchronization point for error recovery. When an error is detected while processing any extended-query message, the backend issues ErrorResponse, then reads and discards messages until a Sync is reached, then issues ReadyForQuery and returns to normal message processing. (But note that no skipping occurs if an error is detected *while* processing Sync — this ensures that there is one and only one ReadyForQuery sent for each Sync.)

> **Note:** Sync does not cause a transaction block opened with `BEGIN` to be closed. It is possible to detect this situation since the ReadyForQuery message includes transaction status information.

In addition to these fundamental, required operations, there are several optional operations that can be used with extended-query protocol.

The Describe message (portal variant) specifies the name of an existing portal (or an empty string for the unnamed portal). The response is a RowDescription message describing the rows that will be returned by executing the portal; or a NoData message if the portal does not contain a query that will return rows; or ErrorResponse if there is no such portal.

The Describe message (statement variant) specifies the name of an existing prepared statement (or an empty string for the unnamed prepared statement). The response is a ParameterDescription message describing the parameters needed by the statement, followed by a RowDescription message describing the rows that will be returned when the statement is eventually executed (or a NoData message if the statement will not return rows). ErrorResponse is issued if there is no such prepared statement. Note that since Bind has not yet been issued, the formats to be used for returned columns are not yet known to the backend; the format code fields in the RowDescription message will be zeroes in this case.

> **Tip:** In most scenarios the frontend should issue one or the other variant of Describe before issuing Execute, to ensure that it knows how to interpret the results it will get back.

The Close message closes an existing prepared statement or portal and releases resources. It is not an error to issue Close against a nonexistent statement or portal name. The response is normally CloseComplete, but could be ErrorResponse if some difficulty is encountered while releasing resources. Note that closing a prepared statement implicitly closes any open portals that were constructed from that statement.

The Flush message does not cause any specific output to be generated, but forces the backend to deliver any data pending in its output buffers. A Flush must be sent after any extended-query command except Sync, if the frontend wishes to examine the results of that command before issuing more commands. Without Flush, messages returned by the backend will be combined into the minimum possible number of packets to minimize network overhead.

> **Note:** The simple Query message is approximately equivalent to the series Parse, Bind, portal Describe, Execute, Close, Sync, using the unnamed prepared statement and portal objects and no parameters. One difference is that it will accept multiple SQL statements in the query string, automatically performing the bind/describe/execute sequence for each one in succession. Another difference is that it will not return ParseComplete, BindComplete, CloseComplete, or NoData messages.

49.2.4. Function Call

The Function Call sub-protocol allows the client to request a direct call of any function that exists in the database's `pg_proc` system catalog. The client must have execute permission for the function.

> **Note:** The Function Call sub-protocol is a legacy feature that is probably best avoided in new code. Similar results can be accomplished by setting up a prepared statement that does `SELECT function($1, ...)`. The Function Call cycle can then be replaced with Bind/Execute.

A Function Call cycle is initiated by the frontend sending a FunctionCall message to the backend. The backend then sends one or more response messages depending on the results of the function call, and finally a ReadyForQuery response message. ReadyForQuery informs the frontend that it can safely send a new query or function call.

The possible response messages from the backend are:

ErrorResponse

An error has occurred.

FunctionCallResponse

The function call was completed and returned the result given in the message. (Note that the Function Call protocol can only handle a single scalar result, not a row type or set of results.)

ReadyForQuery

Processing of the function call is complete. ReadyForQuery will always be sent, whether processing terminates successfully or with an error.

NoticeResponse

A warning message has been issued in relation to the function call. Notices are in addition to other responses, i.e., the backend will continue processing the command.

49.2.5. COPY Operations

The `COPY` command allows high-speed bulk data transfer to or from the server. Copy-in and copy-out operations each switch the connection into a distinct sub-protocol, which lasts until the operation is completed.

Copy-in mode (data transfer to the server) is initiated when the backend executes a `COPY FROM STDIN` SQL statement. The backend sends a CopyInResponse message to the frontend. The frontend should then send zero or more CopyData messages, forming a stream of input data. (The message boundaries are not required to have anything to do with row boundaries, although that is often a reasonable choice.) The frontend can terminate the copy-in mode by sending either a CopyDone message (allowing successful termination) or a CopyFail message (which will cause the `COPY` SQL statement to fail with an error). The backend then reverts to the command-processing mode it was in before the `COPY` started, which will be either simple or extended query protocol. It will next send either CommandComplete (if successful) or ErrorResponse (if not).

In the event of a backend-detected error during copy-in mode (including receipt of a CopyFail message), the backend will issue an ErrorResponse message. If the `COPY` command was issued via an extended-query message, the backend will now discard frontend messages until a Sync message is received, then it will issue ReadyForQuery and return to normal processing. If the `COPY` command was issued in a simple Query message, the rest of that message is discarded and ReadyForQuery is issued. In either case, any subsequent CopyData, CopyDone, or CopyFail messages issued by the frontend will simply be dropped.

The backend will ignore Flush and Sync messages received during copy-in mode. Receipt of any other non-copy message type constitutes an error that will abort the copy-in state as described above. (The exception for Flush and Sync is for the convenience of client libraries that always send Flush or Sync after an Execute message, without checking whether the command to be executed is a `COPY FROM STDIN`.)

Copy-out mode (data transfer from the server) is initiated when the backend executes a `COPY TO STDOUT` SQL statement. The backend sends a CopyOutResponse message to the frontend, followed by zero or more CopyData messages (always one per row), followed by CopyDone. The backend then reverts to the command-processing mode it was in before the `COPY` started, and sends CommandComplete. The frontend cannot abort the transfer (except by closing the connection or issuing a Cancel request), but it can discard unwanted CopyData and CopyDone messages.

In the event of a backend-detected error during copy-out mode, the backend will issue an ErrorResponse message and revert to normal processing. The frontend should treat receipt of ErrorResponse as terminating the copy-out mode.

It is possible for NoticeResponse and ParameterStatus messages to be interspersed between CopyData messages; frontends must handle these cases, and should be prepared for other asynchronous message types as well (see Section 49.2.6). Otherwise, any message type other than CopyData or CopyDone may be treated as terminating copy-out mode.

There is another Copy-related mode called copy-both, which allows high-speed bulk data transfer to *and* from the server. Copy-both mode is initiated when a backend in walsender mode executes a `START_REPLICATION` statement. The backend sends a CopyBothResponse message to the frontend. Both the backend and the frontend may then send CopyData messages until either end sends a CopyDone message. After the client sends a CopyDone message, the connection goes from copy-both mode to copy-out mode, and the client may not send any more CopyData messages. Similarly, when the server sends a CopyDone message, the connection goes into copy-in mode, and the server may not send any more CopyData messages. After both sides have sent a CopyDone message, the copy mode is terminated, and the backend reverts to the command-processing mode. In the event of a backend-detected error during copy-both mode, the backend will issue an ErrorResponse message,

discard frontend messages until a Sync message is received, and then issue ReadyForQuery and return to normal processing. The frontend should treat receipt of ErrorResponse as terminating the copy in both directions; no CopyDone should be sent in this case. See Section 49.3 for more information on the subprotocol transmitted over copy-both mode.

The CopyInResponse, CopyOutResponse and CopyBothResponse messages include fields that inform the frontend of the number of columns per row and the format codes being used for each column. (As of the present implementation, all columns in a given `COPY` operation will use the same format, but the message design does not assume this.)

49.2.6. Asynchronous Operations

There are several cases in which the backend will send messages that are not specifically prompted by the frontend's command stream. Frontends must be prepared to deal with these messages at any time, even when not engaged in a query. At minimum, one should check for these cases before beginning to read a query response.

It is possible for NoticeResponse messages to be generated due to outside activity; for example, if the database administrator commands a "fast" database shutdown, the backend will send a NoticeResponse indicating this fact before closing the connection. Accordingly, frontends should always be prepared to accept and display NoticeResponse messages, even when the connection is nominally idle.

ParameterStatus messages will be generated whenever the active value changes for any of the parameters the backend believes the frontend should know about. Most commonly this occurs in response to a `SET` SQL command executed by the frontend, and this case is effectively synchronous — but it is also possible for parameter status changes to occur because the administrator changed a configuration file and then sent the SIGHUP signal to the server. Also, if a `SET` command is rolled back, an appropriate ParameterStatus message will be generated to report the current effective value.

At present there is a hard-wired set of parameters for which ParameterStatus will be generated: they are `server_version`, `server_encoding`, `client_encoding`, `application_name`, `is_superuser`, `session_authorization`, `DateStyle`, `IntervalStyle`, `TimeZone`, `integer_datetimes`, and `standard_conforming_strings`. (`server_encoding`, `TimeZone`, and `integer_datetimes` were not reported by releases before 8.0; `standard_conforming_strings` was not reported by releases before 8.1; `IntervalStyle` was not reported by releases before 8.4; `application_name` was not reported by releases before 9.0.) Note that `server_version`, `server_encoding` and `integer_datetimes` are pseudo-parameters that cannot change after startup. This set might change in the future, or even become configurable. Accordingly, a frontend should simply ignore ParameterStatus for parameters that it does not understand or care about.

If a frontend issues a `LISTEN` command, then the backend will send a NotificationResponse message (not to be confused with NoticeResponse!) whenever a `NOTIFY` command is executed for the same channel name.

> **Note:** At present, NotificationResponse can only be sent outside a transaction, and thus it will not occur in the middle of a command-response series, though it might occur just before ReadyForQuery. It is unwise to design frontend logic that assumes that, however. Good practice is to be able to accept NotificationResponse at any point in the protocol.

49.2.7. Canceling Requests in Progress

During the processing of a query, the frontend might request cancellation of the query. The cancel request is not sent directly on the open connection to the backend for reasons of implementation efficiency: we don't want to have the backend constantly checking for new input from the frontend during query processing. Cancel requests should be relatively infrequent, so we make them slightly cumbersome in order to avoid a penalty in the normal case.

To issue a cancel request, the frontend opens a new connection to the server and sends a CancelRequest message, rather than the StartupMessage message that would ordinarily be sent across a new connection. The server will process this request and then close the connection. For security reasons, no direct reply is made to the cancel request message.

A CancelRequest message will be ignored unless it contains the same key data (PID and secret key) passed to the frontend during connection start-up. If the request matches the PID and secret key for a currently executing backend, the processing of the current query is aborted. (In the existing implementation, this is done by sending a special signal to the backend process that is processing the query.)

The cancellation signal might or might not have any effect — for example, if it arrives after the backend has finished processing the query, then it will have no effect. If the cancellation is effective, it results in the current command being terminated early with an error message.

The upshot of all this is that for reasons of both security and efficiency, the frontend has no direct way to tell whether a cancel request has succeeded. It must continue to wait for the backend to respond to the query. Issuing a cancel simply improves the odds that the current query will finish soon, and improves the odds that it will fail with an error message instead of succeeding.

Since the cancel request is sent across a new connection to the server and not across the regular frontend/backend communication link, it is possible for the cancel request to be issued by any process, not just the frontend whose query is to be canceled. This might provide additional flexibility when building multiple-process applications. It also introduces a security risk, in that unauthorized persons might try to cancel queries. The security risk is addressed by requiring a dynamically generated secret key to be supplied in cancel requests.

49.2.8. Termination

The normal, graceful termination procedure is that the frontend sends a Terminate message and immediately closes the connection. On receipt of this message, the backend closes the connection and terminates.

In rare cases (such as an administrator-commanded database shutdown) the backend might disconnect without any frontend request to do so. In such cases the backend will attempt to send an error or notice message giving the reason for the disconnection before it closes the connection.

Other termination scenarios arise from various failure cases, such as core dump at one end or the other, loss of the communications link, loss of message-boundary synchronization, etc. If either frontend or backend sees an unexpected closure of the connection, it should clean up and terminate. The frontend has the option of launching a new backend by recontacting the server if it doesn't want to terminate itself. Closing the connection is also advisable if an unrecognizable message type is received, since this probably indicates loss of message-boundary sync.

For either normal or abnormal termination, any open transaction is rolled back, not committed. One should note however that if a frontend disconnects while a non-`SELECT` query is being processed, the backend will probably finish the query before noticing the disconnection. If the query is outside

any transaction block (BEGIN ... COMMIT sequence) then its results might be committed before the disconnection is recognized.

49.2.9. SSL Session Encryption

If PostgreSQL was built with SSL support, frontend/backend communications can be encrypted using SSL. This provides communication security in environments where attackers might be able to capture the session traffic. For more information on encrypting PostgreSQL sessions with SSL, see Section 17.9.

To initiate an SSL-encrypted connection, the frontend initially sends an SSLRequest message rather than a StartupMessage. The server then responds with a single byte containing S or N, indicating that it is willing or unwilling to perform SSL, respectively. The frontend might close the connection at this point if it is dissatisfied with the response. To continue after S, perform an SSL startup handshake (not described here, part of the SSL specification) with the server. If this is successful, continue with sending the usual StartupMessage. In this case the StartupMessage and all subsequent data will be SSL-encrypted. To continue after N, send the usual StartupMessage and proceed without encryption.

The frontend should also be prepared to handle an ErrorMessage response to SSLRequest from the server. This would only occur if the server predates the addition of SSL support to PostgreSQL. (Such servers are now very ancient, and likely do not exist in the wild anymore.) In this case the connection must be closed, but the frontend might choose to open a fresh connection and proceed without requesting SSL.

An initial SSLRequest can also be used in a connection that is being opened to send a CancelRequest message.

While the protocol itself does not provide a way for the server to force SSL encryption, the administrator can configure the server to reject unencrypted sessions as a byproduct of authentication checking.

49.3. Streaming Replication Protocol

To initiate streaming replication, the frontend sends the replication parameter in the startup message. A Boolean value of true tells the backend to go into walsender mode, wherein a small set of replication commands can be issued instead of SQL statements. Only the simple query protocol can be used in walsender mode. Passing database as the value instructs walsender to connect to the database specified in the dbname parameter, which will allow the connection to be used for logical replication from that database.

For the purpose of testing replication commands, you can make a replication connection via psql or any other libpq-using tool with a connection string including the replication option, e.g.:

```
psql "dbname=postgres replication=database" -c "IDENTIFY_SYSTEM;"
```

However it is often more useful to use pg_receivexlog (for physical replication) or pg_recvlogical (for logical replication).

The commands accepted in walsender mode are:

IDENTIFY_SYSTEM

Requests the server to identify itself. Server replies with a result set of a single row, containing four fields:

systemid

The unique system identifier identifying the cluster. This can be used to check that the base backup used to initialize the standby came from the same cluster.

timeline

Current TimelineID. Also useful to check that the standby is consistent with the master.

xlogpos

Current xlog write location. Useful to get a known location in the transaction log where streaming can start.

dbname

Database connected to or NULL.

TIMELINE_HISTORY *tli*

Requests the server to send over the timeline history file for timeline *tli*. Server replies with a result set of a single row, containing two fields:

filename

Filename of the timeline history file, e.g `00000002.history`.

content

Contents of the timeline history file.

CREATE_REPLICATION_SLOT *slot_name* { `PHYSICAL` | `LOGICAL` *output_plugin* }

Create a physical or logical replication slot. See Section 25.2.6 for more about replication slots.

slot_name

The name of the slot to create. Must be a valid replication slot name (see Section 25.2.6.1).

output_plugin

The name of the output plugin used for logical decoding (see Section 46.6).

START_REPLICATION [`SLOT` *slot_name*] [`PHYSICAL`] *XXX/XXX* [`TIMELINE` *tli*]

Instructs server to start streaming WAL, starting at WAL position *XXX/XXX*. If `TIMELINE` option is specified, streaming starts on timeline *tli*; otherwise, the server's current timeline is selected. The server can reply with an error, e.g. if the requested section of WAL has already been recycled. On success, server responds with a CopyBothResponse message, and then starts to stream WAL to the frontend.

If a slot's name is provided via *slot_name*, it will be updated as replication progresses so that the server knows which WAL segments, and if `hot_standby_feedback` is on which transactions, are still needed by the standby.

If the client requests a timeline that's not the latest, but is part of the history of the server, the server will stream all the WAL on that timeline starting from the requested startpoint, up to the point where the server switched to another timeline. If the client requests streaming at exactly the end of an old timeline, the server responds immediately with CommandComplete without entering COPY mode.

After streaming all the WAL on a timeline that is not the latest one, the server will end streaming by exiting the COPY mode. When the client acknowledges this by also exiting COPY mode, the server sends a result set with one row and two columns, indicating the next timeline in this server's history. The first column is the next timeline's ID, and the second column is the XLOG position where the switch happened. Usually, the switch position is the end of the WAL that was streamed, but there are corner cases where the server can send some WAL from the old timeline that it has not itself replayed before promoting. Finally, the server sends CommandComplete message, and is ready to accept a new command.

WAL data is sent as a series of CopyData messages. (This allows other information to be intermixed; in particular the server can send an ErrorResponse message if it encounters a failure after beginning to stream.) The payload of each CopyData message from server to the client contains a message of one of the following formats:

XLogData (B)

Byte1('w')

Identifies the message as WAL data.

Int64

The starting point of the WAL data in this message.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte*n*

A section of the WAL data stream.

A single WAL record is never split across two XLogData messages. When a WAL record crosses a WAL page boundary, and is therefore already split using continuation records, it can be split at the page boundary. In other words, the first main WAL record and its continuation records can be sent in different XLogData messages.

Primary keepalive message (B)

Byte1('k')

Identifies the message as a sender keepalive.

Int64

The current end of WAL on the server.

Int64

The server's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

1 means that the client should reply to this message as soon as possible, to avoid a timeout disconnect. 0 otherwise.

The receiving process can send replies back to the sender at any time, using one of the following message formats (also in the payload of a CopyData message):

Standby status update (F)

Byte1('r')

Identifies the message as a receiver status update.

Int64

The location of the last WAL byte + 1 received and written to disk in the standby.

Int64

The location of the last WAL byte + 1 flushed to disk in the standby.

Int64

The location of the last WAL byte + 1 applied in the standby.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Byte1

If 1, the client requests the server to reply to this message immediately. This can be used to ping the server, to test if the connection is still healthy.

Hot Standby feedback message (F)

Byte1('h')

Identifies the message as a Hot Standby feedback message.

Int64

The client's system clock at the time of transmission, as microseconds since midnight on 2000-01-01.

Int32

The standby's current xmin. This may be 0, if the standby is sending notification that Hot Standby feedback will no longer be sent on this connection. Later non-zero messages may reinitiate the feedback mechanism.

Int32

The standby's current epoch.

START_REPLICATION SLOT *slot_name* LOGICAL *XXX/XXX* [(*option_name* [*option_value*] [, ...])]

Instructs server to start streaming WAL for logical replication, starting at WAL position *XXX/XXX*. The server can reply with an error, e.g. if the requested section of WAL has already been recycled. On success, server responds with a CopyBothResponse message, and then starts to stream WAL to the frontend.

The messages inside the CopyBothResponse messages are of the same format documented for START_REPLICATION ... PHYSICAL.

The output plugin associated with the selected slot is used to process the output for streaming.

SLOT *slot_name*

The name of the slot to stream changes from. This parameter is required, and must correspond to an existing logical replication slot created with CREATE_REPLICATION_SLOT in LOGICAL mode.

XXX/XXX

The WAL position to begin streaming at.

option_name

The name of an option passed to the slot's logical decoding plugin.

option_value

Optional value, in the form of a string constant, associated with the specified option.

DROP_REPLICATION_SLOT *slot_name*

Drops a replication slot, freeing any reserved server-side resources. If the slot is currently in use by an active connection, this command fails.

slot_name

The name of the slot to drop.

BASE_BACKUP [LABEL *'label'*] [PROGRESS] [FAST] [WAL] [NOWAIT] [MAX_RATE *rate*]

Instructs the server to start streaming a base backup. The system will automatically be put in backup mode before the backup is started, and taken out of it when the backup is complete. The following options are accepted:

LABEL *'label'*

Sets the label of the backup. If none is specified, a backup label of base backup will be used. The quoting rules for the label are the same as a standard SQL string with standard_conforming_strings turned on.

PROGRESS

Request information required to generate a progress report. This will send back an approximate size in the header of each tablespace, which can be used to calculate how far along the stream is done. This is calculated by enumerating all the file sizes once before the transfer is even started, and may as such have a negative impact on the performance - in particular it may take longer before the first data is streamed. Since the database files can change during the backup, the size is only approximate and may both grow and shrink between the time of approximation and the sending of the actual files.

FAST

Request a fast checkpoint.

WAL

Include the necessary WAL segments in the backup. This will include all the files between start and stop backup in the pg_xlog directory of the base directory tar file.

NOWAIT

By default, the backup will wait until the last required xlog segment has been archived, or emit a warning if log archiving is not enabled. Specifying NOWAIT disables both the waiting and the warning, leaving the client responsible for ensuring the required log is available.

MAX_RATE *rate*

Limit (throttle) the maximum amount of data transferred from server to client per unit of time. The expected unit is kilobytes per second. If this option is specified, the value must either be equal to zero or it must fall within the range from 32 kB through 1 GB (inclusive). If zero is passed or the option is not specified, no restriction is imposed on the transfer.

When the backup is started, the server will first send two ordinary result sets, followed by one or more CopyResponse results.

The first ordinary result set contains the starting position of the backup, in a single row with two columns. The first column contains the start position given in XLogRecPtr format, and the second column contains the corresponding timeline ID.

The second ordinary result set has one row for each tablespace. The fields in this row are:

spcoid

The oid of the tablespace, or NULL if it's the base directory.

spclocation

The full path of the tablespace directory, or NULL if it's the base directory.

size

The approximate size of the tablespace, if progress report has been requested; otherwise it's NULL.

After the second regular result set, one or more CopyResponse results will be sent, one for PGDATA and one for each additional tablespace other than pg_default and pg_global. The data in the CopyResponse results will be a tar format (following the "ustar interchange format" specified in the POSIX 1003.1-2008 standard) dump of the tablespace contents, except that the two trailing blocks of zeroes specified in the standard are omitted. After the tar data is complete, a final ordinary result set will be sent, containing the WAL end position of the backup, in the same format as the start position.

The tar archive for the data directory and each tablespace will contain all files in the directories, regardless of whether they are PostgreSQL files or other files added to the same directory. The only excluded files are:

- postmaster.pid
- postmaster.opts
- various temporary files created during the operation of the PostgreSQL server
- pg_xlog, including subdirectories. If the backup is run with WAL files included, a synthesized version of pg_xlog will be included, but it will only contain the files necessary for the backup to work, not the rest of the contents.
- pg_replslot is copied as an empty directory.

- Files other than regular files and directories, such as symbolic links and special device files, are skipped. (Symbolic links in `pg_tblspc` are maintained.)

Owner, group and file mode are set if the underlying file system on the server supports it.

Once all tablespaces have been sent, a final regular result set will be sent. This result set contains the end position of the backup, given in XLogRecPtr format as a single column in a single row.

49.4. Message Data Types

This section describes the base data types used in messages.

Int*n*(*i*)

An *n*-bit integer in network byte order (most significant byte first). If *i* is specified it is the exact value that will appear, otherwise the value is variable. Eg. Int16, Int32(42).

Int*n*[*k*]

An array of *k* *n*-bit integers, each in network byte order. The array length *k* is always determined by an earlier field in the message. Eg. Int16[M].

String(*s*)

A null-terminated string (C-style string). There is no specific length limitation on strings. If *s* is specified it is the exact value that will appear, otherwise the value is variable. Eg. String, String("user").

> **Note:** *There is no predefined limit* on the length of a string that can be returned by the backend. Good coding strategy for a frontend is to use an expandable buffer so that anything that fits in memory can be accepted. If that's not feasible, read the full string and discard trailing characters that don't fit into your fixed-size buffer.

Byte*n*(*c*)

Exactly *n* bytes. If the field width *n* is not a constant, it is always determinable from an earlier field in the message. If *c* is specified it is the exact value. Eg. Byte2, Byte1('\n').

49.5. Message Formats

This section describes the detailed format of each message. Each is marked to indicate that it can be sent by a frontend (F), a backend (B), or both (F & B). Notice that although each message includes a byte count at the beginning, the message format is defined so that the message end can be found without reference to the byte count. This aids validity checking. (The CopyData message is an exception, because it forms part of a data stream; the contents of any individual CopyData message cannot be interpretable on their own.)

AuthenticationOk (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(0)

Specifies that the authentication was successful.

AuthenticationKerberosV5 (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(2)

Specifies that Kerberos V5 authentication is required.

AuthenticationCleartextPassword (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(3)

Specifies that a clear-text password is required.

AuthenticationMD5Password (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(12)

Length of message contents in bytes, including self.

Int32(5)

Specifies that an MD5-encrypted password is required.

Byte4

The salt to use when encrypting the password.

AuthenticationSCMCredential (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(6)

Specifies that an SCM credentials message is required.

AuthenticationGSS (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(7)

Specifies that GSSAPI authentication is required.

AuthenticationSSPI (B)

Byte1('R')

Identifies the message as an authentication request.

Int32(8)

Length of message contents in bytes, including self.

Int32(9)

Specifies that SSPI authentication is required.

AuthenticationGSSContinue (B)

Byte1('R')

Identifies the message as an authentication request.

Int32

Length of message contents in bytes, including self.

Int32(8)

Specifies that this message contains GSSAPI or SSPI data.

Byte$n$

GSSAPI or SSPI authentication data.

BackendKeyData (B)

Byte1('K')

Identifies the message as cancellation key data. The frontend must save these values if it wishes to be able to issue CancelRequest messages later.

Int32(12)

Length of message contents in bytes, including self.

Int32

The process ID of this backend.

Int32

The secret key of this backend.

Bind (F)

Byte1('B')

Identifies the message as a Bind command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination portal (an empty string selects the unnamed portal).

String

The name of the source prepared statement (an empty string selects the unnamed prepared statement).

Int16

The number of parameter format codes that follow (denoted C below). This can be zero to indicate that there are no parameters or that the parameters all use the default format (text); or one, in which case the specified format code is applied to all parameters; or it can equal the actual number of parameters.

Int16[C]

The parameter format codes. Each must presently be zero (text) or one (binary).

Int16

The number of parameter values that follow (possibly zero). This must match the number of parameters needed by the query.

Next, the following pair of fields appear for each parameter:

Int32

The length of the parameter value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL parameter value. No value bytes follow in the NULL case.

Byte*n*

The value of the parameter, in the format indicated by the associated format code. *n* is the above length.

After the last parameter, the following fields appear:

Int16

The number of result-column format codes that follow (denoted *R* below). This can be zero to indicate that there are no result columns or that the result columns should all use the default format (text); or one, in which case the specified format code is applied to all result columns (if any); or it can equal the actual number of result columns of the query.

Int16[*R*]

The result-column format codes. Each must presently be zero (text) or one (binary).

BindComplete (B)

Byte1('2')

Identifies the message as a Bind-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CancelRequest (F)

Int32(16)

Length of message contents in bytes, including self.

Int32(80877102)

The cancel request code. The value is chosen to contain `1234` in the most significant 16 bits, and `5678` in the least 16 significant bits. (To avoid confusion, this code must not be the same as any protocol version number.)

Int32

The process ID of the target backend.

Int32

The secret key for the target backend.

Close (F)

Byte1('C')

Identifies the message as a Close command.

Int32

Length of message contents in bytes, including self.

Byte1

'`S`' to close a prepared statement; or '`P`' to close a portal.

String

The name of the prepared statement or portal to close (an empty string selects the unnamed prepared statement or portal).

CloseComplete (B)

Byte1('3')

Identifies the message as a Close-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CommandComplete (B)

Byte1('C')

Identifies the message as a command-completed response.

Int32

Length of message contents in bytes, including self.

String

The command tag. This is usually a single word that identifies which SQL command was completed.

For an `INSERT` command, the tag is `INSERT` *`oid rows`*, where *`rows`* is the number of rows inserted. *`oid`* is the object ID of the inserted row if *`rows`* is 1 and the target table has OIDs; otherwise *`oid`* is 0.

For a `DELETE` command, the tag is `DELETE` *`rows`* where *`rows`* is the number of rows deleted.

For an `UPDATE` command, the tag is `UPDATE` *`rows`* where *`rows`* is the number of rows updated.

For a `SELECT` or `CREATE TABLE AS` command, the tag is `SELECT` *`rows`* where *`rows`* is the number of rows retrieved.

For a `MOVE` command, the tag is `MOVE` *`rows`* where *`rows`* is the number of rows the cursor's position has been changed by.

For a `FETCH` command, the tag is `FETCH` *`rows`* where *`rows`* is the number of rows that have been retrieved from the cursor.

For a `COPY` command, the tag is `COPY` *`rows`* where *`rows`* is the number of rows copied. (Note: the row count appears only in PostgreSQL 8.2 and later.)

CopyData (F & B)

Byte1('d')

Identifies the message as `COPY` data.

Int32

Length of message contents in bytes, including self.

Byte*n*

Data that forms part of a COPY data stream. Messages sent from the backend will always correspond to single data rows, but messages sent by frontends might divide the data stream arbitrarily.

CopyDone (F & B)

Byte1('c')

Identifies the message as a COPY-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

CopyFail (F)

Byte1('f')

Identifies the message as a COPY-failure indicator.

Int32

Length of message contents in bytes, including self.

String

An error message to report as the cause of failure.

CopyInResponse (B)

Byte1('G')

Identifies the message as a Start Copy In response. The frontend must now send copy-in data (if not prepared to do so, send a CopyFail message).

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall COPY format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyOutResponse (B)

Byte1('H')

Identifies the message as a Start Copy Out response. This message will be followed by copy-out data.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall `COPY` format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

CopyBothResponse (B)

Byte1('W')

Identifies the message as a Start Copy Both response. This message is used only for Streaming Replication.

Int32

Length of message contents in bytes, including self.

Int8

0 indicates the overall `COPY` format is textual (rows separated by newlines, columns separated by separator characters, etc). 1 indicates the overall copy format is binary (similar to DataRow format). See COPY for more information.

Int16

The number of columns in the data to be copied (denoted *N* below).

Int16[*N*]

The format codes to be used for each column. Each must presently be zero (text) or one (binary). All must be zero if the overall copy format is textual.

DataRow (B)

Byte1('D')

Identifies the message as a data row.

Int32

Length of message contents in bytes, including self.

Int16

The number of column values that follow (possibly zero).

Next, the following pair of fields appear for each column:

Int32

The length of the column value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL column value. No value bytes follow in the NULL case.

Byte*n*

The value of the column, in the format indicated by the associated format code. *n* is the above length.

Describe (F)

Byte1('D')

Identifies the message as a Describe command.

Int32

Length of message contents in bytes, including self.

Byte1

'S' to describe a prepared statement; or 'P' to describe a portal.

String

The name of the prepared statement or portal to describe (an empty string selects the unnamed prepared statement or portal).

EmptyQueryResponse (B)

Byte1('I')

Identifies the message as a response to an empty query string. (This substitutes for CommandComplete.)

Int32(4)

Length of message contents in bytes, including self.

ErrorResponse (B)

Byte1('E')

Identifies the message as an error.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 49.6. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

Execute (F)

Byte1('E')

Identifies the message as an Execute command.

Int32

Length of message contents in bytes, including self.

String

The name of the portal to execute (an empty string selects the unnamed portal).

Int32

Maximum number of rows to return, if portal contains a query that returns rows (ignored otherwise). Zero denotes "no limit".

Flush (F)

Byte1('H')

Identifies the message as a Flush command.

Int32(4)

Length of message contents in bytes, including self.

FunctionCall (F)

Byte1('F')

Identifies the message as a function call.

Int32

Length of message contents in bytes, including self.

Int32

Specifies the object ID of the function to call.

Int16

The number of argument format codes that follow (denoted `C` below). This can be zero to indicate that there are no arguments or that the arguments all use the default format (text); or one, in which case the specified format code is applied to all arguments; or it can equal the actual number of arguments.

Int16[*C*]

The argument format codes. Each must presently be zero (text) or one (binary).

Int16

Specifies the number of arguments being supplied to the function.

Next, the following pair of fields appear for each argument:

Int32

The length of the argument value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL argument value. No value bytes follow in the NULL case.

Byte*n*

The value of the argument, in the format indicated by the associated format code. *n* is the above length.

After the last argument, the following field appears:

Int16

The format code for the function result. Must presently be zero (text) or one (binary).

FunctionCallResponse (B)

Byte1('V')

Identifies the message as a function call result.

Int32

Length of message contents in bytes, including self.

Int32

The length of the function result value, in bytes (this count does not include itself). Can be zero. As a special case, -1 indicates a NULL function result. No value bytes follow in the NULL case.

Byte*n*

The value of the function result, in the format indicated by the associated format code. *n* is the above length.

NoData (B)

Byte1('n')

Identifies the message as a no-data indicator.

Int32(4)

Length of message contents in bytes, including self.

NoticeResponse (B)

Byte1('N')

Identifies the message as a notice.

Int32

Length of message contents in bytes, including self.

The message body consists of one or more identified fields, followed by a zero byte as a terminator. Fields can appear in any order. For each field there is the following:

Byte1

A code identifying the field type; if zero, this is the message terminator and no string follows. The presently defined field types are listed in Section 49.6. Since more field types might be added in future, frontends should silently ignore fields of unrecognized type.

String

The field value.

NotificationResponse (B)

Byte1('A')

Identifies the message as a notification response.

Int32

Length of message contents in bytes, including self.

Int32

The process ID of the notifying backend process.

String

The name of the channel that the notify has been raised on.

String

The "payload" string passed from the notifying process.

ParameterDescription (B)

Byte1('t')

Identifies the message as a parameter description.

Int32

Length of message contents in bytes, including self.

Int16

The number of parameters used by the statement (can be zero).

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type.

ParameterStatus (B)

Byte1('S')

Identifies the message as a run-time parameter status report.

Int32

Length of message contents in bytes, including self.

String

The name of the run-time parameter being reported.

String

The current value of the parameter.

Parse (F)

Byte1('P')

Identifies the message as a Parse command.

Int32

Length of message contents in bytes, including self.

String

The name of the destination prepared statement (an empty string selects the unnamed prepared statement).

String

The query string to be parsed.

Int16

The number of parameter data types specified (can be zero). Note that this is not an indication of the number of parameters that might appear in the query string, only the number that the frontend wants to prespecify types for.

Then, for each parameter, there is the following:

Int32

Specifies the object ID of the parameter data type. Placing a zero here is equivalent to leaving the type unspecified.

ParseComplete (B)

Byte1('1')

Identifies the message as a Parse-complete indicator.

Int32(4)

Length of message contents in bytes, including self.

PasswordMessage (F)

Byte1('p')

Identifies the message as a password response. Note that this is also used for GSSAPI and SSPI response messages (which is really a design error, since the contained data is not a null-terminated string in that case, but can be arbitrary binary data).

Int32

Length of message contents in bytes, including self.

String

The password (encrypted, if requested).

PortalSuspended (B)

Byte1('s')

Identifies the message as a portal-suspended indicator. Note this only appears if an Execute message's row-count limit was reached.

Int32(4)

Length of message contents in bytes, including self.

Query (F)

Byte1('Q')

Identifies the message as a simple query.

Int32

Length of message contents in bytes, including self.

String

The query string itself.

ReadyForQuery (B)

Byte1('Z')

Identifies the message type. ReadyForQuery is sent whenever the backend is ready for a new query cycle.

Int32(5)

Length of message contents in bytes, including self.

Byte1

Current backend transaction status indicator. Possible values are '`I`' if idle (not in a transaction block); '`T`' if in a transaction block; or '`E`' if in a failed transaction block (queries will be rejected until block is ended).

RowDescription (B)

Byte1('T')

Identifies the message as a row description.

Int32

Length of message contents in bytes, including self.

Int16

Specifies the number of fields in a row (can be zero).

Then, for each field, there is the following:

String

The field name.

Int32

If the field can be identified as a column of a specific table, the object ID of the table; otherwise zero.

Int16

If the field can be identified as a column of a specific table, the attribute number of the column; otherwise zero.

Int32

The object ID of the field's data type.

Int16

The data type size (see `pg_type.typlen`). Note that negative values denote variable-width types.

Int32

The type modifier (see `pg_attribute.atttypmod`). The meaning of the modifier is type-specific.

Int16

The format code being used for the field. Currently will be zero (text) or one (binary). In a RowDescription returned from the statement variant of Describe, the format code is not yet known and will always be zero.

SSLRequest (F)

Int32(8)

Length of message contents in bytes, including self.

Int32(80877103)

The SSL request code. The value is chosen to contain `1234` in the most significant 16 bits, and `5679` in the least 16 significant bits. (To avoid confusion, this code must not be the same as any protocol version number.)

StartupMessage (F)

Int32

Length of message contents in bytes, including self.

Int32(196608)

The protocol version number. The most significant 16 bits are the major version number (3 for the protocol described here). The least significant 16 bits are the minor version number (0 for the protocol described here).

The protocol version number is followed by one or more pairs of parameter name and value strings. A zero byte is required as a terminator after the last name/value pair. Parameters can appear in any order. `user` is required, others are optional. Each parameter is specified as:

String

The parameter name. Currently recognized names are:

`user`

The database user name to connect as. Required; there is no default.

`database`

The database to connect to. Defaults to the user name.

`options`

Command-line arguments for the backend. (This is deprecated in favor of setting individual run-time parameters.)

In addition to the above, any run-time parameter that can be set at backend start time might be listed. Such settings will be applied during backend start (after parsing the command-line options if any). The values will act as session defaults.

String

The parameter value.

Sync (F)

Byte1('S')

Identifies the message as a Sync command.

Int32(4)

Length of message contents in bytes, including self.

Terminate (F)

Byte1('X')

Identifies the message as a termination.

Int32(4)

Length of message contents in bytes, including self.

49.6. Error and Notice Message Fields

This section describes the fields that can appear in ErrorResponse and NoticeResponse messages. Each field type has a single-byte identification token. Note that any given field type should appear at most once per message.

`S`

Severity: the field contents are `ERROR`, `FATAL`, or `PANIC` (in an error message), or `WARNING`, `NOTICE`, `DEBUG`, `INFO`, or `LOG` (in a notice message), or a localized translation of one of these. Always present.

`C`

Code: the SQLSTATE code for the error (see Appendix A). Not localizable. Always present.

`M`

Message: the primary human-readable error message. This should be accurate but terse (typically one line). Always present.

`D`

Detail: an optional secondary error message carrying more detail about the problem. Might run to multiple lines.

`H`

Hint: an optional suggestion what to do about the problem. This is intended to differ from Detail in that it offers advice (potentially inappropriate) rather than hard facts. Might run to multiple lines.

`P`

Position: the field value is a decimal ASCII integer, indicating an error cursor position as an index into the original query string. The first character has index 1, and positions are measured in characters not bytes.

`p`

Internal position: this is defined the same as the `P` field, but it is used when the cursor position refers to an internally generated command rather than the one submitted by the client. The `q` field will always appear when this field appears.

`q`

Internal query: the text of a failed internally-generated command. This could be, for example, a SQL query issued by a PL/pgSQL function.

`W`

Where: an indication of the context in which the error occurred. Presently this includes a call stack traceback of active procedural language functions and internally-generated queries. The trace is one entry per line, most recent first.

`s`

Schema name: if the error was associated with a specific database object, the name of the schema containing that object, if any.

`t`

Table name: if the error was associated with a specific table, the name of the table. (Refer to the schema name field for the name of the table's schema.)

`c`

Column name: if the error was associated with a specific table column, the name of the column. (Refer to the schema and table name fields to identify the table.)

`d`

Data type name: if the error was associated with a specific data type, the name of the data type. (Refer to the schema name field for the name of the data type's schema.)

`n`

Constraint name: if the error was associated with a specific constraint, the name of the constraint. Refer to fields listed above for the associated table or domain. (For this purpose, indexes are treated as constraints, even if they weren't created with constraint syntax.)

`F`

File: the file name of the source-code location where the error was reported.

`L`

Line: the line number of the source-code location where the error was reported.

`R`

Routine: the name of the source-code routine reporting the error.

Note: The fields for schema name, table name, column name, data type name, and constraint name are supplied only for a limited number of error types; see Appendix A. Frontends should not assume that the presence of any of these fields guarantees the presence of another field. Core error sources observe the interrelationships noted above, but user-defined functions may use these fields in other ways. In the same vein, clients should not assume that these fields denote contemporary objects in the current database.

The client is responsible for formatting displayed information to meet its needs; in particular it should break long lines as needed. Newline characters appearing in the error message fields should be treated as paragraph breaks, not line breaks.

49.7. Summary of Changes since Protocol 2.0

This section provides a quick checklist of changes, for the benefit of developers trying to update existing client libraries to protocol 3.0.

The initial startup packet uses a flexible list-of-strings format instead of a fixed format. Notice that session default values for run-time parameters can now be specified directly in the startup packet. (Actually, you could do that before using the `options` field, but given the limited width of `options` and the lack of any way to quote whitespace in the values, it wasn't a very safe technique.)

All messages now have a length count immediately following the message type byte (except for startup packets, which have no type byte). Also note that PasswordMessage now has a type byte.

ErrorResponse and NoticeResponse ('`E`' and '`N`') messages now contain multiple fields, from which the client code can assemble an error message of the desired level of verbosity. Note that individual fields will typically not end with a newline, whereas the single string sent in the older protocol always did.

The ReadyForQuery ('`Z`') message includes a transaction status indicator.

The distinction between BinaryRow and DataRow message types is gone; the single DataRow message type serves for returning data in all formats. Note that the layout of DataRow has changed to make it easier to parse. Also, the representation of binary values has changed: it is no longer directly tied to the server's internal representation.

There is a new "extended query" sub-protocol, which adds the frontend message types Parse, Bind, Execute, Describe, Close, Flush, and Sync, and the backend message types ParseComplete, BindComplete, PortalSuspended, ParameterDescription, NoData, and CloseComplete. Existing clients do not have to concern themselves with this sub-protocol, but making use of it might allow improvements in performance or functionality.

`COPY` data is now encapsulated into CopyData and CopyDone messages. There is a well-defined way to recover from errors during `COPY`. The special "`\.`" last line is not needed anymore, and is not sent during `COPY OUT`. (It is still recognized as a terminator during `COPY IN`, but its use is deprecated and will eventually be removed.) Binary `COPY` is supported. The CopyInResponse and CopyOutResponse messages include fields indicating the number of columns and the format of each column.

The layout of FunctionCall and FunctionCallResponse messages has changed. FunctionCall can now support passing NULL arguments to functions. It also can handle passing parameters and retrieving results in either text or binary format. There is no longer any reason to consider FunctionCall a potential security hole, since it does not offer direct access to internal server data representations.

The backend sends ParameterStatus ('`S`') messages during connection startup for all parameters it considers interesting to the client library. Subsequently, a ParameterStatus message is sent whenever the active value changes for any of these parameters.

The RowDescription ('`T`') message carries new table OID and column number fields for each column of the described row. It also shows the format code for each column.

The CursorResponse ('`P`') message is no longer generated by the backend.

The NotificationResponse ('`A`') message has an additional string field, which can carry a "payload" string passed from the `NOTIFY` event sender.

The EmptyQueryResponse ('`I`') message used to include an empty string parameter; this has been removed.

Chapter 50. PostgreSQL Coding Conventions

50.1. Formatting

Source code formatting uses 4 column tab spacing, with tabs preserved (i.e., tabs are not expanded to spaces). Each logical indentation level is one additional tab stop.

Layout rules (brace positioning, etc) follow BSD conventions. In particular, curly braces for the controlled blocks of `if`, `while`, `switch`, etc go on their own lines.

Limit line lengths so that the code is readable in an 80-column window. (This doesn't mean that you must never go past 80 columns. For instance, breaking a long error message string in arbitrary places just to keep the code within 80 columns is probably not a net gain in readability.)

Do not use C++ style comments (`//` comments). Strict ANSI C compilers do not accept them. For the same reason, do not use C++ extensions such as declaring new variables mid-block.

The preferred style for multi-line comment blocks is

```
/*
 * comment text begins here
 * and continues here
 */
```

Note that comment blocks that begin in column 1 will be preserved as-is by pgindent, but it will reflow indented comment blocks as though they were plain text. If you want to preserve the line breaks in an indented block, add dashes like this:

```
    /*----------
     * comment text begins here
     * and continues here
     *----------
     */
```

While submitted patches do not absolutely have to follow these formatting rules, it's a good idea to do so. Your code will get run through pgindent before the next release, so there's no point in making it look nice under some other set of formatting conventions. A good rule of thumb for patches is "make the new code look like the existing code around it".

The `src/tools` directory contains sample settings files that can be used with the emacs, xemacs or vim editors to help ensure that they format code according to these conventions.

The text browsing tools more and less can be invoked as:

```
more -x4
less -x4
```

to make them show tabs appropriately.

50.2. Reporting Errors Within the Server

Error, warning, and log messages generated within the server code should be created using `ereport`, or its older cousin `elog`. The use of this function is complex enough to require some explanation.

There are two required elements for every message: a severity level (ranging from `DEBUG` to `PANIC`) and a primary message text. In addition there are optional elements, the most common of which is an error identifier code that follows the SQL spec's SQLSTATE conventions. `ereport` itself is just a shell function, that exists mainly for the syntactic convenience of making message generation look like a function call in the C source code. The only parameter accepted directly by `ereport` is the severity level. The primary message text and any optional message elements are generated by calling auxiliary functions, such as `errmsg`, within the `ereport` call.

A typical call to `ereport` might look like this:

```
ereport(ERROR,
        (errcode(ERRCODE_DIVISION_BY_ZERO),
         errmsg("division by zero")));
```

This specifies error severity level `ERROR` (a run-of-the-mill error). The `errcode` call specifies the SQLSTATE error code using a macro defined in `src/include/utils/errcodes.h`. The `errmsg` call provides the primary message text. Notice the extra set of parentheses surrounding the auxiliary function calls — these are annoying but syntactically necessary.

Here is a more complex example:

```
ereport(ERROR,
        (errcode(ERRCODE_AMBIGUOUS_FUNCTION),
         errmsg("function %s is not unique",
                func_signature_string(funcname, nargs,
                                      NIL, actual_arg_types)),
         errhint("Unable to choose a best candidate function. "
                 "You might need to add explicit typecasts.")));
```

This illustrates the use of format codes to embed run-time values into a message text. Also, an optional "hint" message is provided.

If the severity level is `ERROR` or higher, `ereport` aborts the execution of the user-defined function and does not return to the caller. If the severity level is lower than `ERROR`, `ereport` returns normally.

The available auxiliary routines for `ereport` are:

- `errcode(sqlerrcode)` specifies the SQLSTATE error identifier code for the condition. If this routine is not called, the error identifier defaults to `ERRCODE_INTERNAL_ERROR` when the error severity level is `ERROR` or higher, `ERRCODE_WARNING` when the error level is `WARNING`, otherwise (for `NOTICE` and below) `ERRCODE_SUCCESSFUL_COMPLETION`. While these defaults are often convenient, always think whether they are appropriate before omitting the `errcode()` call.
- `errmsg(const char *msg, ...)` specifies the primary error message text, and possibly run-time values to insert into it. Insertions are specified by `sprintf`-style format codes. In addition to the standard format codes accepted by `sprintf`, the format code `%m` can be used to insert the error message returned by `strerror` for the current value of `errno`. [1] `%m` does not require any corresponding entry in the parameter list for `errmsg`. Note that the message string will be run through `gettext` for possible localization before format codes are processed.

1. That is, the value that was current when the `ereport` call was reached; changes of `errno` within the auxiliary reporting routines will not affect it. That would not be true if you were to write `strerror(errno)` explicitly in `errmsg`'s parameter list; accordingly, do not do so.

- `errmsg_internal(const char *msg, ...)` is the same as `errmsg`, except that the message string will not be translated nor included in the internationalization message dictionary. This should be used for "cannot happen" cases that are probably not worth expending translation effort on.
- `errmsg_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errmsg`, but with support for various plural forms of the message. *`fmt_singular`* is the English singular format, *`fmt_plural`* is the English plural format, *`n`* is the integer value that determines which plural form is needed, and the remaining arguments are formatted according to the selected format string. For more information see Section 51.2.2.
- `errdetail(const char *msg, ...)` supplies an optional "detail" message; this is to be used when there is additional information that seems inappropriate to put in the primary message. The message string is processed in just the same way as for `errmsg`.
- `errdetail_internal(const char *msg, ...)` is the same as `errdetail`, except that the message string will not be translated nor included in the internationalization message dictionary. This should be used for detail messages that are not worth expending translation effort on, for instance because they are too technical to be useful to most users.
- `errdetail_plural(const char *fmt_singular, const char *fmt_plural, unsigned long n, ...)` is like `errdetail`, but with support for various plural forms of the message. For more information see Section 51.2.2.
- `errdetail_log(const char *msg, ...)` is the same as `errdetail` except that this string goes only to the server log, never to the client. If both `errdetail` (or one of its equivalents above) and `errdetail_log` are used then one string goes to the client and the other to the log. This is useful for error details that are too security-sensitive or too bulky to include in the report sent to the client.
- `errdetail_log_plural(const char *fmt_singuar, const char *fmt_plural, unsigned long n, ...)` is like `errdetail_log`, but with support for various plural forms of the message. For more information see Section 51.2.2.
- `errhint(const char *msg, ...)` supplies an optional "hint" message; this is to be used when offering suggestions about how to fix the problem, as opposed to factual details about what went wrong. The message string is processed in just the same way as for `errmsg`.
- `errcontext(const char *msg, ...)` is not normally called directly from an `ereport` message site; rather it is used in `error_context_stack` callback functions to provide information about the context in which an error occurred, such as the current location in a PL function. The message string is processed in just the same way as for `errmsg`. Unlike the other auxiliary functions, this can be called more than once per `ereport` call; the successive strings thus supplied are concatenated with separating newlines.
- `errposition(int cursorpos)` specifies the textual location of an error within a query string. Currently it is only useful for errors detected in the lexical and syntactic analysis phases of query processing.
- `errtable(Relation rel)` specifies a relation whose name and schema name should be included as auxiliary fields in the error report.
- `errtablecol(Relation rel, int attnum)` specifies a column whose name, table name, and schema name should be included as auxiliary fields in the error report.
- `errtableconstraint(Relation rel, const char *conname)` specifies a table constraint whose name, table name, and schema name should be included as auxiliary fields in the error report. Indexes should be considered to be constraints for this purpose, whether or not they have an associated `pg_constraint` entry. Be careful to pass the underlying heap relation, not the index itself, as `rel`.

- `errdatatype(Oid datatypeOid)` specifies a data type whose name and schema name should be included as auxiliary fields in the error report.
- `errdomainconstraint(Oid datatypeOid, const char *conname)` specifies a domain constraint whose name, domain name, and schema name should be included as auxiliary fields in the error report.
- `errcode_for_file_access()` is a convenience function that selects an appropriate SQLSTATE error identifier for a failure in a file-access-related system call. It uses the saved `errno` to determine which error code to generate. Usually this should be used in combination with `%m` in the primary error message text.
- `errcode_for_socket_access()` is a convenience function that selects an appropriate SQLSTATE error identifier for a failure in a socket-related system call.
- `errhidestmt(bool hide_stmt)` can be called to specify suppression of the `STATEMENT:` portion of a message in the postmaster log. Generally this is appropriate if the message text includes the current statement already.

> **Note:** At most one of the functions `errtable`, `errtablecol`, `errtableconstraint`, `errdatatype`, or `errdomainconstraint` should be used in an `ereport` call. These functions exist to allow applications to extract the name of a database object associated with the error condition without having to examine the potentially-localized error message text. These functions should be used in error reports for which it's likely that applications would wish to have automatic error handling. As of PostgreSQL 9.3, complete coverage exists only for errors in SQLSTATE class 23 (integrity constraint violation), but this is likely to be expanded in future.

There is an older function `elog` that is still heavily used. An `elog` call:

```
elog(level, "format string", ...);
```

is exactly equivalent to:

```
ereport(level, (errmsg_internal("format string", ...)));
```

Notice that the SQLSTATE error code is always defaulted, and the message string is not subject to translation. Therefore, `elog` should be used only for internal errors and low-level debug logging. Any message that is likely to be of interest to ordinary users should go through `ereport`. Nonetheless, there are enough internal "cannot happen" error checks in the system that `elog` is still widely used; it is preferred for those messages for its notational simplicity.

Advice about writing good error messages can be found in Section 50.3.

50.3. Error Message Style Guide

This style guide is offered in the hope of maintaining a consistent, user-friendly style throughout all the messages generated by PostgreSQL.

50.3.1. What Goes Where

The primary message should be short, factual, and avoid reference to implementation details such as specific function names. "Short" means "should fit on one line under normal conditions". Use a detail

message if needed to keep the primary message short, or if you feel a need to mention implementation details such as the particular system call that failed. Both primary and detail messages should be factual. Use a hint message for suggestions about what to do to fix the problem, especially if the suggestion might not always be applicable.

For example, instead of:

```
IpcMemoryCreate: shmget(key=%d, size=%u, 0%o) failed: %m
(plus a long addendum that is basically a hint)
```

write:

```
Primary:    could not create shared memory segment: %m
Detail:     Failed syscall was shmget(key=%d, size=%u, 0%o).
Hint:       the addendum
```

Rationale: keeping the primary message short helps keep it to the point, and lets clients lay out screen space on the assumption that one line is enough for error messages. Detail and hint messages can be relegated to a verbose mode, or perhaps a pop-up error-details window. Also, details and hints would normally be suppressed from the server log to save space. Reference to implementation details is best avoided since users don't know the details anyway.

50.3.2. Formatting

Don't put any specific assumptions about formatting into the message texts. Expect clients and the server log to wrap lines to fit their own needs. In long messages, newline characters (\n) can be used to indicate suggested paragraph breaks. Don't end a message with a newline. Don't use tabs or other formatting characters. (In error context displays, newlines are automatically added to separate levels of context such as function calls.)

Rationale: Messages are not necessarily displayed on terminal-type displays. In GUI displays or browsers these formatting instructions are at best ignored.

50.3.3. Quotation Marks

English text should use double quotes when quoting is appropriate. Text in other languages should consistently use one kind of quotes that is consistent with publishing customs and computer output of other programs.

Rationale: The choice of double quotes over single quotes is somewhat arbitrary, but tends to be the preferred use. Some have suggested choosing the kind of quotes depending on the type of object according to SQL conventions (namely, strings single quoted, identifiers double quoted). But this is a language-internal technical issue that many users aren't even familiar with, it won't scale to other kinds of quoted terms, it doesn't translate to other languages, and it's pretty pointless, too.

50.3.4. Use of Quotes

Use quotes always to delimit file names, user-supplied identifiers, and other variables that might contain words. Do not use them to mark up variables that will not contain words (for example, operator names).

There are functions in the backend that will double-quote their own output at need (for example, `format_type_be()`). Do not put additional quotes around the output of such functions.

Rationale: Objects can have names that create ambiguity when embedded in a message. Be consistent about denoting where a plugged-in name starts and ends. But don't clutter messages with unnecessary or duplicate quote marks.

50.3.5. Grammar and Punctuation

The rules are different for primary error messages and for detail/hint messages:

Primary error messages: Do not capitalize the first letter. Do not end a message with a period. Do not even think about ending a message with an exclamation point.

Detail and hint messages: Use complete sentences, and end each with a period. Capitalize the first word of sentences. Put two spaces after the period if another sentence follows (for English text; might be inappropriate in other languages).

Error context strings: Do not capitalize the first letter and do not end the string with a period. Context strings should normally not be complete sentences.

Rationale: Avoiding punctuation makes it easier for client applications to embed the message into a variety of grammatical contexts. Often, primary messages are not grammatically complete sentences anyway. (And if they're long enough to be more than one sentence, they should be split into primary and detail parts.) However, detail and hint messages are longer and might need to include multiple sentences. For consistency, they should follow complete-sentence style even when there's only one sentence.

50.3.6. Upper Case vs. Lower Case

Use lower case for message wording, including the first letter of a primary error message. Use upper case for SQL commands and key words if they appear in the message.

Rationale: It's easier to make everything look more consistent this way, since some messages are complete sentences and some not.

50.3.7. Avoid Passive Voice

Use the active voice. Use complete sentences when there is an acting subject ("A could not do B"). Use telegram style without subject if the subject would be the program itself; do not use "I" for the program.

Rationale: The program is not human. Don't pretend otherwise.

50.3.8. Present vs. Past Tense

Use past tense if an attempt to do something failed, but could perhaps succeed next time (perhaps after fixing some problem). Use present tense if the failure is certainly permanent.

There is a nontrivial semantic difference between sentences of the form:

```
could not open file "%s": %m
```

and:

```
cannot open file "%s"
```

The first one means that the attempt to open the file failed. The message should give a reason, such as "disk full" or "file doesn't exist". The past tense is appropriate because next time the disk might not be full anymore or the file in question might exist.

The second form indicates that the functionality of opening the named file does not exist at all in the program, or that it's conceptually impossible. The present tense is appropriate because the condition will persist indefinitely.

Rationale: Granted, the average user will not be able to draw great conclusions merely from the tense of the message, but since the language provides us with a grammar we should use it correctly.

50.3.9. Type of the Object

When citing the name of an object, state what kind of object it is.

Rationale: Otherwise no one will know what "foo.bar.baz" refers to.

50.3.10. Brackets

Square brackets are only to be used (1) in command synopses to denote optional arguments, or (2) to denote an array subscript.

Rationale: Anything else does not correspond to widely-known customary usage and will confuse people.

50.3.11. Assembling Error Messages

When a message includes text that is generated elsewhere, embed it in this style:

```
could not open file %s: %m
```

Rationale: It would be difficult to account for all possible error codes to paste this into a single smooth sentence, so some sort of punctuation is needed. Putting the embedded text in parentheses has also been suggested, but it's unnatural if the embedded text is likely to be the most important part of the message, as is often the case.

50.3.12. Reasons for Errors

Messages should always state the reason why an error occurred. For example:

```
BAD:    could not open file %s
BETTER: could not open file %s (I/O failure)
```

If no reason is known you better fix the code.

50.3.13. Function Names

Don't include the name of the reporting routine in the error text. We have other mechanisms for finding that out when needed, and for most users it's not helpful information. If the error text doesn't make as much sense without the function name, reword it.

```
BAD:    pg_atoi: error in "z": cannot parse "z"
BETTER: invalid input syntax for integer: "z"
```

Avoid mentioning called function names, either; instead say what the code was trying to do:

```
BAD:    open() failed: %m
BETTER: could not open file %s: %m
```

If it really seems necessary, mention the system call in the detail message. (In some cases, providing the actual values passed to the system call might be appropriate information for the detail message.)

Rationale: Users don't know what all those functions do.

50.3.14. Tricky Words to Avoid

Unable. "Unable" is nearly the passive voice. Better use "cannot" or "could not", as appropriate.

Bad. Error messages like "bad result" are really hard to interpret intelligently. It's better to write why the result is "bad", e.g., "invalid format".

Illegal. "Illegal" stands for a violation of the law, the rest is "invalid". Better yet, say why it's invalid.

Unknown. Try to avoid "unknown". Consider "error: unknown response". If you don't know what the response is, how do you know it's erroneous? "Unrecognized" is often a better choice. Also, be sure to include the value being complained of.

```
BAD:    unknown node type
BETTER: unrecognized node type: 42
```

Find vs. Exists. If the program uses a nontrivial algorithm to locate a resource (e.g., a path search) and that algorithm fails, it is fair to say that the program couldn't "find" the resource. If, on the other hand, the expected location of the resource is known but the program cannot access it there then say that the resource doesn't "exist". Using "find" in this case sounds weak and confuses the issue.

May vs. Can vs. Might. "May" suggests permission (e.g., "You may borrow my rake."), and has little use in documentation or error messages. "Can" suggests ability (e.g., "I can lift that log."), and "might" suggests possibility (e.g., "It might rain today."). Using the proper word clarifies meaning and assists translation.

Contractions. Avoid contractions, like "can't"; use "cannot" instead.

50.3.15. Proper Spelling

Spell out words in full. For instance, avoid:

- spec
- stats

- parens
- auth
- xact

Rationale: This will improve consistency.

50.3.16. Localization

Keep in mind that error message texts need to be translated into other languages. Follow the guidelines in Section 51.2.2 to avoid making life difficult for translators.

Chapter 51. Native Language Support

51.1. For the Translator

PostgreSQL programs (server and client) can issue their messages in your favorite language — if the messages have been translated. Creating and maintaining translated message sets needs the help of people who speak their own language well and want to contribute to the PostgreSQL effort. You do not have to be a programmer at all to do this. This section explains how to help.

51.1.1. Requirements

We won't judge your language skills — this section is about software tools. Theoretically, you only need a text editor. But this is only in the unlikely event that you do not want to try out your translated messages. When you configure your source tree, be sure to use the `--enable-nls` option. This will also check for the libintl library and the `msgfmt` program, which all end users will need anyway. To try out your work, follow the applicable portions of the installation instructions.

If you want to start a new translation effort or want to do a message catalog merge (described later), you will need the programs `xgettext` and `msgmerge`, respectively, in a GNU-compatible implementation. Later, we will try to arrange it so that if you use a packaged source distribution, you won't need `xgettext`. (If working from Git, you will still need it.) GNU Gettext 0.10.36 or later is currently recommended.

Your local gettext implementation should come with its own documentation. Some of that is probably duplicated in what follows, but for additional details you should look there.

51.1.2. Concepts

The pairs of original (English) messages and their (possibly) translated equivalents are kept in *message catalogs*, one for each program (although related programs can share a message catalog) and for each target language. There are two file formats for message catalogs: The first is the "PO" file (for Portable Object), which is a plain text file with special syntax that translators edit. The second is the "MO" file (for Machine Object), which is a binary file generated from the respective PO file and is used while the internationalized program is run. Translators do not deal with MO files; in fact hardly anyone does.

The extension of the message catalog file is to no surprise either `.po` or `.mo`. The base name is either the name of the program it accompanies, or the language the file is for, depending on the situation. This is a bit confusing. Examples are `psql.po` (PO file for psql) or `fr.mo` (MO file in French).

The file format of the PO files is illustrated here:

```
# comment

msgid "original string"
msgstr "translated string"

msgid "more original"
```

```
msgstr "another translated"
"string can be broken up like this"

...
```

The msgid's are extracted from the program source. (They need not be, but this is the most common way.) The msgstr lines are initially empty and are filled in with useful strings by the translator. The strings can contain C-style escape characters and can be continued across lines as illustrated. (The next line must start at the beginning of the line.)

The # character introduces a comment. If whitespace immediately follows the # character, then this is a comment maintained by the translator. There can also be automatic comments, which have a non-whitespace character immediately following the #. These are maintained by the various tools that operate on the PO files and are intended to aid the translator.

```
#. automatic comment
#: filename.c:1023
#, flags, flags
```

The #. style comments are extracted from the source file where the message is used. Possibly the programmer has inserted information for the translator, such as about expected alignment. The #: comment indicates the exact location(s) where the message is used in the source. The translator need not look at the program source, but he can if there is doubt about the correct translation. The #, comments contain flags that describe the message in some way. There are currently two flags: `fuzzy` is set if the message has possibly been outdated because of changes in the program source. The translator can then verify this and possibly remove the fuzzy flag. Note that fuzzy messages are not made available to the end user. The other flag is `c-format`, which indicates that the message is a `printf`-style format template. This means that the translation should also be a format string with the same number and type of placeholders. There are tools that can verify this, which key off the c-format flag.

51.1.3. Creating and Maintaining Message Catalogs

OK, so how does one create a "blank" message catalog? First, go into the directory that contains the program whose messages you want to translate. If there is a file `nls.mk`, then this program has been prepared for translation.

If there are already some `.po` files, then someone has already done some translation work. The files are named *`language`*`.po`, where *`language`* is the ISO 639-1 two-letter language code (in lower case)[1], e.g., `fr.po` for French. If there is really a need for more than one translation effort per language then the files can also be named *`language_region`*`.po` where *`region`* is the ISO 3166-1 two-letter country code (in upper case)[2], e.g., `pt_BR.po` for Portuguese in Brazil. If you find the language you wanted you can just start working on that file.

If you need to start a new translation effort, then first run the command:

```
make init-po
```

This will create a file *`progname`*`.pot`. (`.pot` to distinguish it from PO files that are "in production". The `T` stands for "template".) Copy this file to *`language`*`.po` and edit it. To make it known that the new language is available, also edit the file `nls.mk` and add the language (or language and country) code to the line that looks like:

1. http://www.loc.gov/standards/iso639-2/php/English_list.php
2. http://www.iso.org/iso/country_names_and_code_elements

```
AVAIL_LANGUAGES := de fr
```

(Other languages can appear, of course.)

As the underlying program or library changes, messages might be changed or added by the programmers. In this case you do not need to start from scratch. Instead, run the command:

```
make update-po
```

which will create a new blank message catalog file (the pot file you started with) and will merge it with the existing PO files. If the merge algorithm is not sure about a particular message it marks it "fuzzy" as explained above. The new PO file is saved with a `.po.new` extension.

51.1.4. Editing the PO Files

The PO files can be edited with a regular text editor. The translator should only change the area between the quotes after the msgstr directive, add comments, and alter the fuzzy flag. There is (unsurprisingly) a PO mode for Emacs, which I find quite useful.

The PO files need not be completely filled in. The software will automatically fall back to the original string if no translation (or an empty translation) is available. It is no problem to submit incomplete translations for inclusions in the source tree; that gives room for other people to pick up your work. However, you are encouraged to give priority to removing fuzzy entries after doing a merge. Remember that fuzzy entries will not be installed; they only serve as reference for what might be the right translation.

Here are some things to keep in mind while editing the translations:

- Make sure that if the original ends with a newline, the translation does, too. Similarly for tabs, etc.
- If the original is a `printf` format string, the translation also needs to be. The translation also needs to have the same format specifiers in the same order. Sometimes the natural rules of the language make this impossible or at least awkward. In that case you can modify the format specifiers like this:

  ```
  msgstr "Die Datei %2$s hat %1$u Zeichen."
  ```

  Then the first placeholder will actually use the second argument from the list. The *`digits`*`$` needs to follow the % immediately, before any other format manipulators. (This feature really exists in the `printf` family of functions. You might not have heard of it before because there is little use for it outside of message internationalization.)
- If the original string contains a linguistic mistake, report that (or fix it yourself in the program source) and translate normally. The corrected string can be merged in when the program sources have been updated. If the original string contains a factual mistake, report that (or fix it yourself) and do not translate it. Instead, you can mark the string with a comment in the PO file.
- Maintain the style and tone of the original string. Specifically, messages that are not sentences (`cannot open file %s`) should probably not start with a capital letter (if your language distinguishes letter case) or end with a period (if your language uses punctuation marks). It might help to read Section 50.3.
- If you don't know what a message means, or if it is ambiguous, ask on the developers' mailing list. Chances are that English speaking end users might also not understand it or find it ambiguous, so it's best to improve the message.

51.2. For the Programmer

51.2.1. Mechanics

This section describes how to implement native language support in a program or library that is part of the PostgreSQL distribution. Currently, it only applies to C programs.

Adding NLS Support to a Program

1. Insert this code into the start-up sequence of the program:

   ```
   #ifdef ENABLE_NLS
   #include <locale.h>
   #endif

   ...

   #ifdef ENABLE_NLS
   setlocale(LC_ALL, "");
   bindtextdomain("progname", LOCALEDIR);
   textdomain("progname");
   #endif
   ```

   (The *progname* can actually be chosen freely.)

2. Wherever a message that is a candidate for translation is found, a call to `gettext()` needs to be inserted. E.g.:

   ```
   fprintf(stderr, "panic level %d\n", lvl);
   ```

   would be changed to:

   ```
   fprintf(stderr, gettext("panic level %d\n"), lvl);
   ```

   (`gettext` is defined as a no-op if NLS support is not configured.)

   This tends to add a lot of clutter. One common shortcut is to use:

   ```
   #define _(x) gettext(x)
   ```

   Another solution is feasible if the program does much of its communication through one or a few functions, such as `ereport()` in the backend. Then you make this function call `gettext` internally on all input strings.

3. Add a file `nls.mk` in the directory with the program sources. This file will be read as a makefile. The following variable assignments need to be made here:

`CATALOG_NAME`

The program name, as provided in the `textdomain()` call.

`AVAIL_LANGUAGES`

List of provided translations — initially empty.

`GETTEXT_FILES`

List of files that contain translatable strings, i.e., those marked with `gettext` or an alternative solution. Eventually, this will include nearly all source files of the program. If this list gets too long you can make the first "file" be a `+` and the second word be a file that contains one file name per line.

`GETTEXT_TRIGGERS`

The tools that generate message catalogs for the translators to work on need to know what function calls contain translatable strings. By default, only `gettext()` calls are known. If you used _ or other identifiers you need to list them here. If the translatable string is not the first argument, the item needs to be of the form `func:2` (for the second argument). If you have a function that supports pluralized messages, the item should look like `func:1,2` (identifying the singular and plural message arguments).

The build system will automatically take care of building and installing the message catalogs.

51.2.2. Message-writing Guidelines

Here are some guidelines for writing messages that are easily translatable.

- Do not construct sentences at run-time, like:

  ```
  printf("Files were %s.\n", flag ? "copied" : "removed");
  ```

  The word order within the sentence might be different in other languages. Also, even if you remember to call `gettext()` on each fragment, the fragments might not translate well separately. It's better to duplicate a little code so that each message to be translated is a coherent whole. Only numbers, file names, and such-like run-time variables should be inserted at run time into a message text.

- For similar reasons, this won't work:

  ```
  printf("copied %d file%s", n, n!=1 ? "s" : "");
  ```

  because it assumes how the plural is formed. If you figured you could solve it like this:

  ```
  if (n==1)
      printf("copied 1 file");
  else
      printf("copied %d files", n):
  ```

  then be disappointed. Some languages have more than two forms, with some peculiar rules. It's often best to design the message to avoid the issue altogether, for instance like this:

  ```
  printf("number of copied files: %d", n);
  ```

  If you really want to construct a properly pluralized message, there is support for this, but it's a bit awkward. When generating a primary or detail error message in `ereport()`, you can write something like this:

  ```
  errmsg_plural("copied %d file",
                "copied %d files",
                n,
                n)
  ```

  The first argument is the format string appropriate for English singular form, the second is the format string appropriate for English plural form, and the third is the integer control value that determines which plural form to use. Subsequent arguments are formatted per the format string as usual. (Normally, the pluralization control value will also be one of the values to be formatted, so it has to be written twice.) In English it only matters whether *n* is 1 or not 1, but in other languages there can be many different plural forms. The translator sees the two English forms as a group and has the opportunity to supply multiple substitute strings, with the appropriate one being selected based on the run-time value of *n*.

If you need to pluralize a message that isn't going directly to an `errmsg` or `errdetail` report, you have to use the underlying function `ngettext`. See the gettext documentation.

- If you want to communicate something to the translator, such as about how a message is intended to line up with other output, precede the occurrence of the string with a comment that starts with `translator`, e.g.:

  ```
  /* translator: This message is not what it seems to be. */
  ```

  These comments are copied to the message catalog files so that the translators can see them.

Chapter 52. Writing A Procedural Language Handler

All calls to functions that are written in a language other than the current "version 1" interface for compiled languages (this includes functions in user-defined procedural languages, functions written in SQL, and functions using the version 0 compiled language interface) go through a *call handler* function for the specific language. It is the responsibility of the call handler to execute the function in a meaningful way, such as by interpreting the supplied source text. This chapter outlines how a new procedural language's call handler can be written.

The call handler for a procedural language is a "normal" function that must be written in a compiled language such as C, using the version-1 interface, and registered with PostgreSQL as taking no arguments and returning the type `language_handler`. This special pseudotype identifies the function as a call handler and prevents it from being called directly in SQL commands. For more details on C language calling conventions and dynamic loading, see Section 35.9.

The call handler is called in the same way as any other function: It receives a pointer to a `FunctionCallInfoData struct` containing argument values and information about the called function, and it is expected to return a `Datum` result (and possibly set the `isnull` field of the `FunctionCallInfoData` structure, if it wishes to return an SQL null result). The difference between a call handler and an ordinary callee function is that the `flinfo->fn_oid` field of the `FunctionCallInfoData` structure will contain the OID of the actual function to be called, not of the call handler itself. The call handler must use this field to determine which function to execute. Also, the passed argument list has been set up according to the declaration of the target function, not of the call handler.

It's up to the call handler to fetch the entry of the function from the `pg_proc` system catalog and to analyze the argument and return types of the called function. The `AS` clause from the `CREATE FUNCTION` command for the function will be found in the `prosrc` column of the `pg_proc` row. This is commonly source text in the procedural language, but in theory it could be something else, such as a path name to a file, or anything else that tells the call handler what to do in detail.

Often, the same function is called many times per SQL statement. A call handler can avoid repeated lookups of information about the called function by using the `flinfo->fn_extra` field. This will initially be `NULL`, but can be set by the call handler to point at information about the called function. On subsequent calls, if `flinfo->fn_extra` is already non-`NULL` then it can be used and the information lookup step skipped. The call handler must make sure that `flinfo->fn_extra` is made to point at memory that will live at least until the end of the current query, since an `FmgrInfo` data structure could be kept that long. One way to do this is to allocate the extra data in the memory context specified by `flinfo->fn_mcxt`; such data will normally have the same lifespan as the `FmgrInfo` itself. But the handler could also choose to use a longer-lived memory context so that it can cache function definition information across queries.

When a procedural-language function is invoked as a trigger, no arguments are passed in the usual way, but the `FunctionCallInfoData`'s `context` field points at a `TriggerData` structure, rather than being `NULL` as it is in a plain function call. A language handler should provide mechanisms for procedural-language functions to get at the trigger information.

This is a template for a procedural-language handler written in C:

```
#include "postgres.h"
```

```
#include "executor/spi.h"
#include "commands/trigger.h"
#include "fmgr.h"
#include "access/heapam.h"
#include "utils/syscache.h"
#include "catalog/pg_proc.h"
#include "catalog/pg_type.h"

#ifdef PG_MODULE_MAGIC
PG_MODULE_MAGIC;
#endif

PG_FUNCTION_INFO_V1(plsample_call_handler);

Datum
plsample_call_handler(PG_FUNCTION_ARGS)
{
    Datum          retval;

    if (CALLED_AS_TRIGGER(fcinfo))
    {
        /*
         * Called as a trigger procedure
         */
        TriggerData    *trigdata = (TriggerData *) fcinfo->context;

        retval = ...
    }
    else
    {
        /*
         * Called as a function
         */

        retval = ...
    }

    return retval;
}
```

Only a few thousand lines of code have to be added instead of the dots to complete the call handler.

After having compiled the handler function into a loadable module (see Section 35.9.6), the following commands then register the sample procedural language:

```
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
    AS 'filename'
    LANGUAGE C;
CREATE LANGUAGE plsample
    HANDLER plsample_call_handler;
```

Although providing a call handler is sufficient to create a minimal procedural language, there are two other functions that can optionally be provided to make the language more convenient to use. These are a *validator* and an *inline handler*. A validator can be provided to allow language-specific checking to be done during CREATE FUNCTION. An inline handler can be provided to allow the language to support anonymous code blocks executed via the DO command.

If a validator is provided by a procedural language, it must be declared as a function taking a single parameter of type `oid`. The validator's result is ignored, so it is customarily declared to return `void`. The validator will be called at the end of a `CREATE FUNCTION` command that has created or updated a function written in the procedural language. The passed-in OID is the OID of the function's `pg_proc` row. The validator must fetch this row in the usual way, and do whatever checking is appropriate. First, call `CheckFunctionValidatorAccess()` to diagnose explicit calls to the validator that the user could not achieve through `CREATE FUNCTION`. Typical checks then include verifying that the function's argument and result types are supported by the language, and that the function's body is syntactically correct in the language. If the validator finds the function to be okay, it should just return. If it finds an error, it should report that via the normal `ereport()` error reporting mechanism. Throwing an error will force a transaction rollback and thus prevent the incorrect function definition from being committed.

Validator functions should typically honor the check_function_bodies parameter: if it is turned off then any expensive or context-sensitive checking should be skipped. If the language provides for code execution at compilation time, the validator must suppress checks that would induce such execution. In particular, this parameter is turned off by pg_dump so that it can load procedural language functions without worrying about side effects or dependencies of the function bodies on other database objects. (Because of this requirement, the call handler should avoid assuming that the validator has fully checked the function. The point of having a validator is not to let the call handler omit checks, but to notify the user immediately if there are obvious errors in a `CREATE FUNCTION` command.) While the choice of exactly what to check is mostly left to the discretion of the validator function, note that the core `CREATE FUNCTION` code only executes `SET` clauses attached to a function when `check_function_bodies` is on. Therefore, checks whose results might be affected by GUC parameters definitely should be skipped when `check_function_bodies` is off, to avoid false failures when reloading a dump.

If an inline handler is provided by a procedural language, it must be declared as a function taking a single parameter of type `internal`. The inline handler's result is ignored, so it is customarily declared to return `void`. The inline handler will be called when a `DO` statement is executed specifying the procedural language. The parameter actually passed is a pointer to an `InlineCodeBlock` struct, which contains information about the `DO` statement's parameters, in particular the text of the anonymous code block to be executed. The inline handler should execute this code and return.

It's recommended that you wrap all these function declarations, as well as the `CREATE LANGUAGE` command itself, into an *extension* so that a simple `CREATE EXTENSION` command is sufficient to install the language. See Section 35.15 for information about writing extensions.

The procedural languages included in the standard distribution are good references when trying to write your own language handler. Look into the `src/pl` subdirectory of the source tree. The CREATE LANGUAGE reference page also has some useful details.

Chapter 53. Writing A Foreign Data Wrapper

All operations on a foreign table are handled through its foreign data wrapper, which consists of a set of functions that the core server calls. The foreign data wrapper is responsible for fetching data from the remote data source and returning it to the PostgreSQL executor. If updating foreign tables is to be supported, the wrapper must handle that, too. This chapter outlines how to write a new foreign data wrapper.

The foreign data wrappers included in the standard distribution are good references when trying to write your own. Look into the `contrib` subdirectory of the source tree. The CREATE FOREIGN DATA WRAPPER reference page also has some useful details.

> **Note:** The SQL standard specifies an interface for writing foreign data wrappers. However, PostgreSQL does not implement that API, because the effort to accommodate it into PostgreSQL would be large, and the standard API hasn't gained wide adoption anyway.

53.1. Foreign Data Wrapper Functions

The FDW author needs to implement a handler function, and optionally a validator function. Both functions must be written in a compiled language such as C, using the version-1 interface. For details on C language calling conventions and dynamic loading, see Section 35.9.

The handler function simply returns a struct of function pointers to callback functions that will be called by the planner, executor, and various maintenance commands. Most of the effort in writing an FDW is in implementing these callback functions. The handler function must be registered with PostgreSQL as taking no arguments and returning the special pseudo-type `fdw_handler`. The callback functions are plain C functions and are not visible or callable at the SQL level. The callback functions are described in Section 53.2.

The validator function is responsible for validating options given in `CREATE` and `ALTER` commands for its foreign data wrapper, as well as foreign servers, user mappings, and foreign tables using the wrapper. The validator function must be registered as taking two arguments, a text array containing the options to be validated, and an OID representing the type of object the options are associated with (in the form of the OID of the system catalog the object would be stored in, either `ForeignDataWrapperRelationId`, `ForeignServerRelationId`, `UserMappingRelationId`, or `ForeignTableRelationId`). If no validator function is supplied, options are not checked at object creation time or object alteration time.

53.2. Foreign Data Wrapper Callback Routines

The FDW handler function returns a palloc'd `FdwRoutine` struct containing pointers to the callback functions described below. The scan-related functions are required, the rest are optional.

The `FdwRoutine` struct type is declared in `src/include/foreign/fdwapi.h`, which see for additional details.

53.2.1. FDW Routines For Scanning Foreign Tables

```
void
GetForeignRelSize (PlannerInfo *root,
                   RelOptInfo *baserel,
                   Oid foreigntableid);
```

Obtain relation size estimates for a foreign table. This is called at the beginning of planning for a query that scans a foreign table. `root` is the planner's global information about the query; `baserel` is the planner's information about this table; and `foreigntableid` is the `pg_class` OID of the foreign table. (`foreigntableid` could be obtained from the planner data structures, but it's passed explicitly to save effort.)

This function should update `baserel->rows` to be the expected number of rows returned by the table scan, after accounting for the filtering done by the restriction quals. The initial value of `baserel->rows` is just a constant default estimate, which should be replaced if at all possible. The function may also choose to update `baserel->width` if it can compute a better estimate of the average result row width.

See Section 53.4 for additional information.

```
void
GetForeignPaths (PlannerInfo *root,
                 RelOptInfo *baserel,
                 Oid foreigntableid);
```

Create possible access paths for a scan on a foreign table. This is called during query planning. The parameters are the same as for `GetForeignRelSize`, which has already been called.

This function must generate at least one access path (`ForeignPath` node) for a scan on the foreign table and must call `add_path` to add each such path to `baserel->pathlist`. It's recommended to use `create_foreignscan_path` to build the `ForeignPath` nodes. The function can generate multiple access paths, e.g., a path which has valid `pathkeys` to represent a pre-sorted result. Each access path must contain cost estimates, and can contain any FDW-private information that is needed to identify the specific scan method intended.

See Section 53.4 for additional information.

```
ForeignScan *
GetForeignPlan (PlannerInfo *root,
                RelOptInfo *baserel,
                Oid foreigntableid,
                ForeignPath *best_path,
                List *tlist,
                List *scan_clauses);
```

Create a `ForeignScan` plan node from the selected foreign access path. This is called at the end of query planning. The parameters are as for `GetForeignRelSize`, plus the selected `ForeignPath` (previously produced by `GetForeignPaths`), the target list to be emitted by the plan node, and the restriction clauses to be enforced by the plan node.

This function must create and return a `ForeignScan` plan node; it's recommended to use `make_foreignscan` to build the `ForeignScan` node.

See Section 53.4 for additional information.

```
void
```

```
BeginForeignScan (ForeignScanState *node,
                  int eflags);
```

Begin executing a foreign scan. This is called during executor startup. It should perform any initialization needed before the scan can start, but not start executing the actual scan (that should be done upon the first call to `IterateForeignScan`). The `ForeignScanState` node has already been created, but its `fdw_state` field is still NULL. Information about the table to scan is accessible through the `ForeignScanState` node (in particular, from the underlying `ForeignScan` plan node, which contains any FDW-private information provided by `GetForeignPlan`). `eflags` contains flag bits describing the executor's operating mode for this plan node.

Note that when `(eflags & EXEC_FLAG_EXPLAIN_ONLY)` is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for `ExplainForeignScan` and `EndForeignScan`.

```
TupleTableSlot *
IterateForeignScan (ForeignScanState *node);
```

Fetch one row from the foreign source, returning it in a tuple table slot (the node's `ScanTupleSlot` should be used for this purpose). Return NULL if no more rows are available. The tuple table slot infrastructure allows either a physical or virtual tuple to be returned; in most cases the latter choice is preferable from a performance standpoint. Note that this is called in a short-lived memory context that will be reset between invocations. Create a memory context in `BeginForeignScan` if you need longer-lived storage, or use the `es_query_cxt` of the node's `EState`.

The rows returned must match the column signature of the foreign table being scanned. If you choose to optimize away fetching columns that are not needed, you should insert nulls in those column positions.

Note that PostgreSQL's executor doesn't care whether the rows returned violate any `NOT NULL` constraints that were defined on the foreign table columns — but the planner does care, and may optimize queries incorrectly if `NULL` values are present in a column declared not to contain them. If a `NULL` value is encountered when the user has declared that none should be present, it may be appropriate to raise an error (just as you would need to do in the case of a data type mismatch).

```
void
ReScanForeignScan (ForeignScanState *node);
```

Restart the scan from the beginning. Note that any parameters the scan depends on may have changed value, so the new scan does not necessarily return exactly the same rows.

```
void
EndForeignScan (ForeignScanState *node);
```

End the scan and release resources. It is normally not important to release palloc'd memory, but for example open files and connections to remote servers should be cleaned up.

53.2.2. FDW Routines For Updating Foreign Tables

If an FDW supports writable foreign tables, it should provide some or all of the following callback functions depending on the needs and capabilities of the FDW:

```
void
AddForeignUpdateTargets (Query *parsetree,
```

```
                                RangeTblEntry *target_rte,
                                Relation target_relation);
```

UPDATE and DELETE operations are performed against rows previously fetched by the table-scanning functions. The FDW may need extra information, such as a row ID or the values of primary-key columns, to ensure that it can identify the exact row to update or delete. To support that, this function can add extra hidden, or "junk", target columns to the list of columns that are to be retrieved from the foreign table during an UPDATE or DELETE.

To do that, add TargetEntry items to parsetree->targetList, containing expressions for the extra values to be fetched. Each such entry must be marked resjunk = true, and must have a distinct resname that will identify it at execution time. Avoid using names matching ctid*N*, wholerow, or wholerow*N*, as the core system can generate junk columns of these names.

This function is called in the rewriter, not the planner, so the information available is a bit different from that available to the planning routines. parsetree is the parse tree for the UPDATE or DELETE command, while target_rte and target_relation describe the target foreign table.

If the AddForeignUpdateTargets pointer is set to NULL, no extra target expressions are added. (This will make it impossible to implement DELETE operations, though UPDATE may still be feasible if the FDW relies on an unchanging primary key to identify rows.)

```
List *
PlanForeignModify (PlannerInfo *root,
                   ModifyTable *plan,
                   Index resultRelation,
                   int subplan_index);
```

Perform any additional planning actions needed for an insert, update, or delete on a foreign table. This function generates the FDW-private information that will be attached to the ModifyTable plan node that performs the update action. This private information must have the form of a List, and will be delivered to BeginForeignModify during the execution stage.

root is the planner's global information about the query. plan is the ModifyTable plan node, which is complete except for the fdwPrivLists field. resultRelation identifies the target foreign table by its range table index. subplan_index identifies which target of the ModifyTable plan node this is, counting from zero; use this if you want to index into plan->plans or other substructure of the plan node.

See Section 53.4 for additional information.

If the PlanForeignModify pointer is set to NULL, no additional plan-time actions are taken, and the fdw_private list delivered to BeginForeignModify will be NIL.

```
void
BeginForeignModify (ModifyTableState *mtstate,
                    ResultRelInfo *rinfo,
                    List *fdw_private,
                    int subplan_index,
                    int eflags);
```

Begin executing a foreign table modification operation. This routine is called during executor startup. It should perform any initialization needed prior to the actual table modifications. Subsequently, ExecForeignInsert, ExecForeignUpdate or ExecForeignDelete will be called for each tuple to be inserted, updated, or deleted.

mtstate is the overall state of the ModifyTable plan node being executed; global data about the plan and execution state is available via this structure. rinfo is the ResultRelInfo struct describing the target foreign table. (The ri_FdwState field of ResultRelInfo is available for the FDW to store any private state it needs for this operation.) fdw_private contains the private data generated by PlanForeignModify, if any. subplan_index identifies which target of the ModifyTable plan node this is. eflags contains flag bits describing the executor's operating mode for this plan node.

Note that when (eflags & EXEC_FLAG_EXPLAIN_ONLY) is true, this function should not perform any externally-visible actions; it should only do the minimum required to make the node state valid for ExplainForeignModify and EndForeignModify.

If the BeginForeignModify pointer is set to NULL, no action is taken during executor startup.

```
TupleTableSlot *
ExecForeignInsert (EState *estate,
                   ResultRelInfo *rinfo,
                   TupleTableSlot *slot,
                   TupleTableSlot *planSlot);
```

Insert one tuple into the foreign table. estate is global execution state for the query. rinfo is the ResultRelInfo struct describing the target foreign table. slot contains the tuple to be inserted; it will match the row-type definition of the foreign table. planSlot contains the tuple that was generated by the ModifyTable plan node's subplan; it differs from slot in possibly containing additional "junk" columns. (The planSlot is typically of little interest for INSERT cases, but is provided for completeness.)

The return value is either a slot containing the data that was actually inserted (this might differ from the data supplied, for example as a result of trigger actions), or NULL if no row was actually inserted (again, typically as a result of triggers). The passed-in slot can be re-used for this purpose.

The data in the returned slot is used only if the INSERT query has a RETURNING clause or the foreign table has an AFTER ROW trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the RETURNING clause. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the ExecForeignInsert pointer is set to NULL, attempts to insert into the foreign table will fail with an error message.

```
TupleTableSlot *
ExecForeignUpdate (EState *estate,
                   ResultRelInfo *rinfo,
                   TupleTableSlot *slot,
                   TupleTableSlot *planSlot);
```

Update one tuple in the foreign table. estate is global execution state for the query. rinfo is the ResultRelInfo struct describing the target foreign table. slot contains the new data for the tuple; it will match the row-type definition of the foreign table. planSlot contains the tuple that was generated by the ModifyTable plan node's subplan; it differs from slot in possibly containing additional "junk" columns. In particular, any junk columns that were requested by AddForeignUpdateTargets will be available from this slot.

The return value is either a slot containing the row as it was actually updated (this might differ from the data supplied, for example as a result of trigger actions), or NULL if no row was actually updated (again, typically as a result of triggers). The passed-in slot can be re-used for this purpose.

The data in the returned slot is used only if the UPDATE query has a RETURNING clause or the foreign table has an AFTER ROW trigger. Triggers require all columns, but the FDW could choose to optimize

away returning some or all columns depending on the contents of the RETURNING clause. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the ExecForeignUpdate pointer is set to NULL, attempts to update the foreign table will fail with an error message.

```
TupleTableSlot *
ExecForeignDelete (EState *estate,
                   ResultRelInfo *rinfo,
                   TupleTableSlot *slot,
                   TupleTableSlot *planSlot);
```

Delete one tuple from the foreign table. estate is global execution state for the query. rinfo is the ResultRelInfo struct describing the target foreign table. slot contains nothing useful upon call, but can be used to hold the returned tuple. planSlot contains the tuple that was generated by the ModifyTable plan node's subplan; in particular, it will carry any junk columns that were requested by AddForeignUpdateTargets. The junk column(s) must be used to identify the tuple to be deleted.

The return value is either a slot containing the row that was deleted, or NULL if no row was deleted (typically as a result of triggers). The passed-in slot can be used to hold the tuple to be returned.

The data in the returned slot is used only if the DELETE query has a RETURNING clause or the foreign table has an AFTER ROW trigger. Triggers require all columns, but the FDW could choose to optimize away returning some or all columns depending on the contents of the RETURNING clause. Regardless, some slot must be returned to indicate success, or the query's reported row count will be wrong.

If the ExecForeignDelete pointer is set to NULL, attempts to delete from the foreign table will fail with an error message.

```
void
EndForeignModify (EState *estate,
                  ResultRelInfo *rinfo);
```

End the table update and release resources. It is normally not important to release palloc'd memory, but for example open files and connections to remote servers should be cleaned up.

If the EndForeignModify pointer is set to NULL, no action is taken during executor shutdown.

```
int
IsForeignRelUpdatable (Relation rel);
```

Report which update operations the specified foreign table supports. The return value should be a bit mask of rule event numbers indicating which operations are supported by the foreign table, using the CmdType enumeration; that is, (1 << CMD_UPDATE) = 4 for UPDATE, (1 << CMD_INSERT) = 8 for INSERT, and (1 << CMD_DELETE) = 16 for DELETE.

If the IsForeignRelUpdatable pointer is set to NULL, foreign tables are assumed to be insertable, updatable, or deletable if the FDW provides ExecForeignInsert, ExecForeignUpdate, or ExecForeignDelete respectively. This function is only needed if the FDW supports some tables that are updatable and some that are not. (Even then, it's permissible to throw an error in the execution routine instead of checking in this function. However, this function is used to determine updatability for display in the information_schema views.)

53.2.3. FDW Routines for EXPLAIN

```
void
ExplainForeignScan (ForeignScanState *node,
                    ExplainState *es);
```

Print additional EXPLAIN output for a foreign table scan. This function can call ExplainPropertyText and related functions to add fields to the EXPLAIN output. The flag fields in es can be used to determine what to print, and the state of the ForeignScanState node can be inspected to provide run-time statistics in the EXPLAIN ANALYZE case.

If the ExplainForeignScan pointer is set to NULL, no additional information is printed during EXPLAIN.

```
void
ExplainForeignModify (ModifyTableState *mtstate,
                      ResultRelInfo *rinfo,
                      List *fdw_private,
                      int subplan_index,
                      struct ExplainState *es);
```

Print additional EXPLAIN output for a foreign table update. This function can call ExplainPropertyText and related functions to add fields to the EXPLAIN output. The flag fields in es can be used to determine what to print, and the state of the ModifyTableState node can be inspected to provide run-time statistics in the EXPLAIN ANALYZE case. The first four arguments are the same as for BeginForeignModify.

If the ExplainForeignModify pointer is set to NULL, no additional information is printed during EXPLAIN.

53.2.4. FDW Routines for ANALYZE

```
bool
AnalyzeForeignTable (Relation relation,
                     AcquireSampleRowsFunc *func,
                     BlockNumber *totalpages);
```

This function is called when ANALYZE is executed on a foreign table. If the FDW can collect statistics for this foreign table, it should return true, and provide a pointer to a function that will collect sample rows from the table in func, plus the estimated size of the table in pages in totalpages. Otherwise, return false.

If the FDW does not support collecting statistics for any tables, the AnalyzeForeignTable pointer can be set to NULL.

If provided, the sample collection function must have the signature

```
int
AcquireSampleRowsFunc (Relation relation, int elevel,
                       HeapTuple *rows, int targrows,
                       double *totalrows,
                       double *totaldeadrows);
```

A random sample of up to targrows rows should be collected from the table and stored into the caller-provided rows array. The actual number of rows collected must be returned. In addition, store

estimates of the total numbers of live and dead rows in the table into the output parameters `totalrows` and `totaldeadrows`. (Set `totaldeadrows` to zero if the FDW does not have any concept of dead rows.)

53.3. Foreign Data Wrapper Helper Functions

Several helper functions are exported from the core server so that authors of foreign data wrappers can get easy access to attributes of FDW-related objects, such as FDW options. To use any of these functions, you need to include the header file `foreign/foreign.h` in your source file. That header also defines the struct types that are returned by these functions.

```
ForeignDataWrapper *
GetForeignDataWrapper(Oid fdwid);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given OID. A `ForeignDataWrapper` object contains properties of the FDW (see `foreign/foreign.h` for details).

```
ForeignServer *
GetForeignServer(Oid serverid);
```

This function returns a `ForeignServer` object for the foreign server with the given OID. A `ForeignServer` object contains properties of the server (see `foreign/foreign.h` for details).

```
UserMapping *
GetUserMapping(Oid userid, Oid serverid);
```

This function returns a `UserMapping` object for the user mapping of the given role on the given server. (If there is no mapping for the specific user, it will return the mapping for `PUBLIC`, or throw error if there is none.) A `UserMapping` object contains properties of the user mapping (see `foreign/foreign.h` for details).

```
ForeignTable *
GetForeignTable(Oid relid);
```

This function returns a `ForeignTable` object for the foreign table with the given OID. A `ForeignTable` object contains properties of the foreign table (see `foreign/foreign.h` for details).

```
List *
GetForeignColumnOptions(Oid relid, AttrNumber attnum);
```

This function returns the per-column FDW options for the column with the given foreign table OID and attribute number, in the form of a list of `DefElem`. NIL is returned if the column has no options.

Some object types have name-based lookup functions in addition to the OID-based ones:

```
ForeignDataWrapper *
GetForeignDataWrapperByName(const char *name, bool missing_ok);
```

This function returns a `ForeignDataWrapper` object for the foreign-data wrapper with the given name. If the wrapper is not found, return NULL if missing_ok is true, otherwise raise an error.

```
ForeignServer *
GetForeignServerByName(const char *name, bool missing_ok);
```

This function returns a `ForeignServer` object for the foreign server with the given name. If the server is not found, return NULL if missing_ok is true, otherwise raise an error.

53.4. Foreign Data Wrapper Query Planning

The FDW callback functions `GetForeignRelSize`, `GetForeignPaths`, `GetForeignPlan`, and `PlanForeignModify` must fit into the workings of the PostgreSQL planner. Here are some notes about what they must do.

The information in `root` and `baserel` can be used to reduce the amount of information that has to be fetched from the foreign table (and therefore reduce the cost). `baserel->baserestrictinfo` is particularly interesting, as it contains restriction quals (`WHERE` clauses) that should be used to filter the rows to be fetched. (The FDW itself is not required to enforce these quals, as the core executor can check them instead.) `baserel->reltargetlist` can be used to determine which columns need to be fetched; but note that it only lists columns that have to be emitted by the `ForeignScan` plan node, not columns that are used in qual evaluation but not output by the query.

Various private fields are available for the FDW planning functions to keep information in. Generally, whatever you store in FDW private fields should be palloc'd, so that it will be reclaimed at the end of planning.

`baserel->fdw_private` is a `void` pointer that is available for FDW planning functions to store information relevant to the particular foreign table. The core planner does not touch it except to initialize it to NULL when the `baserel` node is created. It is useful for passing information forward from `GetForeignRelSize` to `GetForeignPaths` and/or `GetForeignPaths` to `GetForeignPlan`, thereby avoiding recalculation.

`GetForeignPaths` can identify the meaning of different access paths by storing private information in the `fdw_private` field of `ForeignPath` nodes. `fdw_private` is declared as a `List` pointer, but could actually contain anything since the core planner does not touch it. However, best practice is to use a representation that's dumpable by `nodeToString`, for use with debugging support available in the backend.

`GetForeignPlan` can examine the `fdw_private` field of the selected `ForeignPath` node, and can generate `fdw_exprs` and `fdw_private` lists to be placed in the `ForeignScan` plan node, where they will be available at execution time. Both of these lists must be represented in a form that `copyObject` knows how to copy. The `fdw_private` list has no other restrictions and is not interpreted by the core backend in any way. The `fdw_exprs` list, if not NIL, is expected to contain expression trees that are intended to be executed at run time. These trees will undergo post-processing by the planner to make them fully executable.

In `GetForeignPlan`, generally the passed-in target list can be copied into the plan node as-is. The passed `scan_clauses` list contains the same clauses as `baserel->baserestrictinfo`, but may be re-ordered for better execution efficiency. In simple cases the FDW can just strip `RestrictInfo` nodes from the `scan_clauses` list (using `extract_actual_clauses`) and put all the clauses into the plan node's qual list, which means that all the clauses will be checked by the executor at run time. More complex FDWs may be able to check some of the clauses internally, in which case those clauses can be removed from the plan node's qual list so that the executor doesn't waste time rechecking them.

As an example, the FDW might identify some restriction clauses of the form *`foreign_variable = sub_expression`*, which it determines can be executed on the remote server given the locally-evaluated value of the *`sub_expression`*. The actual identification of such a clause should

happen during GetForeignPaths, since it would affect the cost estimate for the path. The path's fdw_private field would probably include a pointer to the identified clause's RestrictInfo node. Then GetForeignPlan would remove that clause from scan_clauses, but add the *sub_expression* to fdw_exprs to ensure that it gets massaged into executable form. It would probably also put control information into the plan node's fdw_private field to tell the execution functions what to do at run time. The query transmitted to the remote server would involve something like WHERE *foreign_variable* = $1, with the parameter value obtained at run time from evaluation of the fdw_exprs expression tree.

The FDW should always construct at least one path that depends only on the table's restriction clauses. In join queries, it might also choose to construct path(s) that depend on join clauses, for example *foreign_variable = local_variable*. Such clauses will not be found in baserel->baserestrictinfo but must be sought in the relation's join lists. A path using such a clause is called a "parameterized path". It must identify the other relations used in the selected join clause(s) with a suitable value of param_info; use get_baserel_parampathinfo to compute that value. In GetForeignPlan, the *local_variable* portion of the join clause would be added to fdw_exprs, and then at run time the case works the same as for an ordinary restriction clause.

When planning an UPDATE or DELETE, PlanForeignModify can look up the RelOptInfo struct for the foreign table and make use of the baserel->fdw_private data previously created by the scan-planning functions. However, in INSERT the target table is not scanned so there is no RelOptInfo for it. The List returned by PlanForeignModify has the same restrictions as the fdw_private list of a ForeignScan plan node, that is it must contain only structures that copyObject knows how to copy.

For an UPDATE or DELETE against an external data source that supports concurrent updates, it is recommended that the ForeignScan operation lock the rows that it fetches, perhaps via the equivalent of SELECT FOR UPDATE. The FDW may also choose to lock rows at fetch time when the foreign table is referenced in a SELECT FOR UPDATE/SHARE; if it does not, the FOR UPDATE or FOR SHARE option is essentially a no-op so far as the foreign table is concerned. This behavior may yield semantics slightly different from operations on local tables, where row locking is customarily delayed as long as possible: remote rows may get locked even though they subsequently fail locally-applied restriction or join conditions. However, matching the local semantics exactly would require an additional remote access for every row, and might be impossible anyway depending on what locking semantics the external data source provides.

Chapter 54. Genetic Query Optimizer

Author: Written by Martin Utesch (<utesch@aut.tu-freiberg.de>) for the Institute of Automatic Control at the University of Mining and Technology in Freiberg, Germany.

54.1. Query Handling as a Complex Optimization Problem

Among all relational operators the most difficult one to process and optimize is the *join*. The number of possible query plans grows exponentially with the number of joins in the query. Further optimization effort is caused by the support of a variety of *join methods* (e.g., nested loop, hash join, merge join in PostgreSQL) to process individual joins and a diversity of *indexes* (e.g., B-tree, hash, GiST and GIN in PostgreSQL) as access paths for relations.

The normal PostgreSQL query optimizer performs a *near-exhaustive search* over the space of alternative strategies. This algorithm, first introduced in IBM's System R database, produces a near-optimal join order, but can take an enormous amount of time and memory space when the number of joins in the query grows large. This makes the ordinary PostgreSQL query optimizer inappropriate for queries that join a large number of tables.

The Institute of Automatic Control at the University of Mining and Technology, in Freiberg, Germany, encountered some problems when it wanted to use PostgreSQL as the backend for a decision support knowledge based system for the maintenance of an electrical power grid. The DBMS needed to handle large join queries for the inference machine of the knowledge based system. The number of joins in these queries made using the normal query optimizer infeasible.

In the following we describe the implementation of a *genetic algorithm* to solve the join ordering problem in a manner that is efficient for queries involving large numbers of joins.

54.2. Genetic Algorithms

The genetic algorithm (GA) is a heuristic optimization method which operates through randomized search. The set of possible solutions for the optimization problem is considered as a *population* of *individuals*. The degree of adaptation of an individual to its environment is specified by its *fitness*.

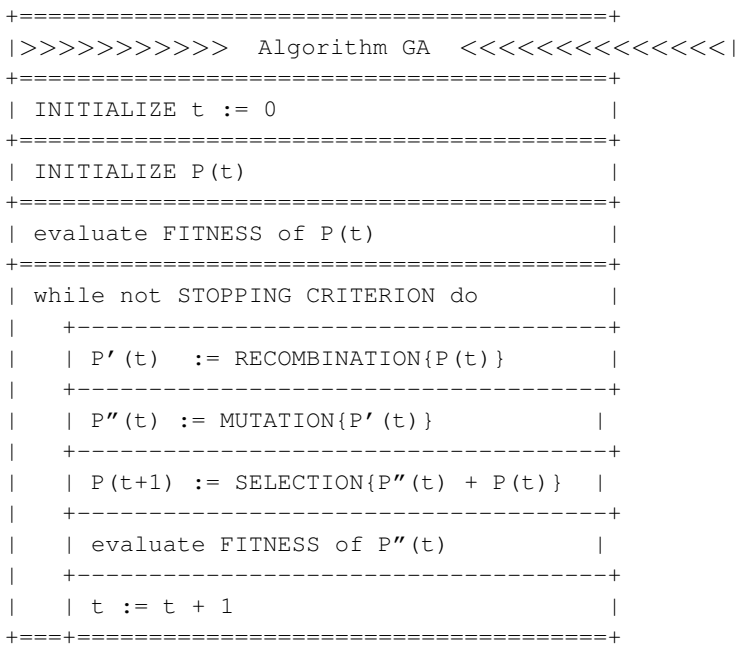
The coordinates of an individual in the search space are represented by *chromosomes*, in essence a set of character strings. A *gene* is a subsection of a chromosome which encodes the value of a single parameter being optimized. Typical encodings for a gene could be *binary* or *integer*.

Through simulation of the evolutionary operations *recombination*, *mutation*, and *selection* new generations of search points are found that show a higher average fitness than their ancestors.

According to the comp.ai.genetic FAQ it cannot be stressed too strongly that a GA is not a pure random search for a solution to a problem. A GA uses stochastic processes, but the result is distinctly non-random (better than random).

Figure 54-1. Structured Diagram of a Genetic Algorithm

P(t)	generation of ancestors at a time t
P”(t)	generation of descendants at a time t



54.3. Genetic Query Optimization (GEQO) in PostgreSQL

The GEQO module approaches the query optimization problem as though it were the well-known traveling salesman problem (TSP). Possible query plans are encoded as integer strings. Each string represents the join order from one relation of the query to the next. For example, the join tree

```
   /\
  /\ 2
 /\ 3
4  1
```

is encoded by the integer string ’4-1-3-2’, which means, first join relation ’4’ and ’1’, then ’3’, and then ’2’, where 1, 2, 3, 4 are relation IDs within the PostgreSQL optimizer.

Specific characteristics of the GEQO implementation in PostgreSQL are:

- Usage of a *steady state* GA (replacement of the least fit individuals in a population, not whole-generational replacement) allows fast convergence towards improved query plans. This is essential for query handling with reasonable time;

- Usage of *edge recombination crossover* which is especially suited to keep edge losses low for the solution of the TSP by means of a GA;
- Mutation as genetic operator is deprecated so that no repair mechanisms are needed to generate legal TSP tours.

Parts of the GEQO module are adapted from D. Whitley's Genitor algorithm.

The GEQO module allows the PostgreSQL query optimizer to support large join queries effectively through non-exhaustive search.

54.3.1. Generating Possible Plans with GEQO

The GEQO planning process uses the standard planner code to generate plans for scans of individual relations. Then join plans are developed using the genetic approach. As shown above, each candidate join plan is represented by a sequence in which to join the base relations. In the initial stage, the GEQO code simply generates some possible join sequences at random. For each join sequence considered, the standard planner code is invoked to estimate the cost of performing the query using that join sequence. (For each step of the join sequence, all three possible join strategies are considered; and all the initially-determined relation scan plans are available. The estimated cost is the cheapest of these possibilities.) Join sequences with lower estimated cost are considered "more fit" than those with higher cost. The genetic algorithm discards the least fit candidates. Then new candidates are generated by combining genes of more-fit candidates — that is, by using randomly-chosen portions of known low-cost join sequences to create new sequences for consideration. This process is repeated until a preset number of join sequences have been considered; then the best one found at any time during the search is used to generate the finished plan.

This process is inherently nondeterministic, because of the randomized choices made during both the initial population selection and subsequent "mutation" of the best candidates. To avoid surprising changes of the selected plan, each run of the GEQO algorithm restarts its random number generator with the current geqo_seed parameter setting. As long as `geqo_seed` and the other GEQO parameters are kept fixed, the same plan will be generated for a given query (and other planner inputs such as statistics). To experiment with different search paths, try changing `geqo_seed`.

54.3.2. Future Implementation Tasks for PostgreSQL GEQO

Work is still needed to improve the genetic algorithm parameter settings. In file `src/backend/optimizer/geqo/geqo_main.c`, routines `gimme_pool_size` and `gimme_number_generations`, we have to find a compromise for the parameter settings to satisfy two competing demands:

- Optimality of the query plan
- Computing time

In the current implementation, the fitness of each candidate join sequence is estimated by running the standard planner's join selection and cost estimation code from scratch. To the extent that different candidates use similar sub-sequences of joins, a great deal of work will be repeated. This could be made significantly faster by retaining cost estimates for sub-joins. The problem is to avoid expending unreasonable amounts of memory on retaining that state.

At a more basic level, it is not clear that solving query optimization with a GA algorithm designed for TSP is appropriate. In the TSP case, the cost associated with any substring (partial tour) is independent of the rest of the tour, but this is certainly not true for query optimization. Thus it is questionable whether edge recombination crossover is the most effective mutation procedure.

54.4. Further Reading

The following resources contain additional information about genetic algorithms:

- The Hitch-Hiker's Guide to Evolutionary Computation[1], (FAQ for news://comp.ai.genetic)
- Evolutionary Computation and its application to art and design[2], by Craig Reynolds
- *Fundamentals of Database Systems*
- *The design and implementation of the POSTGRES query optimizer*

1. http://www.aip.de/~ast/EvolCompFAQ/
2. http://www.red3d.com/cwr/evolve.html

Chapter 55. Index Access Method Interface Definition

This chapter defines the interface between the core PostgreSQL system and *index access methods*, which manage individual index types. The core system knows nothing about indexes beyond what is specified here, so it is possible to develop entirely new index types by writing add-on code.

All indexes in PostgreSQL are what are known technically as *secondary indexes*; that is, the index is physically separate from the table file that it describes. Each index is stored as its own physical *relation* and so is described by an entry in the `pg_class` catalog. The contents of an index are entirely under the control of its index access method. In practice, all index access methods divide indexes into standard-size pages so that they can use the regular storage manager and buffer manager to access the index contents. (All the existing index access methods furthermore use the standard page layout described in Section 59.6, and they all use the same format for index tuple headers; but these decisions are not forced on an access method.)

An index is effectively a mapping from some data key values to *tuple identifiers*, or TIDs, of row versions (tuples) in the index's parent table. A TID consists of a block number and an item number within that block (see Section 59.6). This is sufficient information to fetch a particular row version from the table. Indexes are not directly aware that under MVCC, there might be multiple extant versions of the same logical row; to an index, each tuple is an independent object that needs its own index entry. Thus, an update of a row always creates all-new index entries for the row, even if the key values did not change. (HOT tuples are an exception to this statement; but indexes do not deal with those, either.) Index entries for dead tuples are reclaimed (by vacuuming) when the dead tuples themselves are reclaimed.

55.1. Catalog Entries for Indexes

Each index access method is described by a row in the `pg_am` system catalog (see Section 48.3). The principal contents of a `pg_am` row are references to `pg_proc` entries that identify the index access functions supplied by the access method. The APIs for these functions are defined later in this chapter. In addition, the `pg_am` row specifies a few fixed properties of the access method, such as whether it can support multicolumn indexes. There is not currently any special support for creating or deleting `pg_am` entries; anyone able to write a new access method is expected to be competent to insert an appropriate row for themselves.

To be useful, an index access method must also have one or more *operator families* and *operator classes* defined in `pg_opfamily`, `pg_opclass`, `pg_amop`, and `pg_amproc`. These entries allow the planner to determine what kinds of query qualifications can be used with indexes of this access method. Operator families and classes are described in Section 35.14, which is prerequisite material for reading this chapter.

An individual index is defined by a `pg_class` entry that describes it as a physical relation, plus a `pg_index` entry that shows the logical content of the index — that is, the set of index columns it has and the semantics of those columns, as captured by the associated operator classes. The index columns (key values) can be either simple columns of the underlying table or expressions over the table rows. The index access method normally has no interest in where the index key values come from (it is always handed precomputed key values) but it will be very interested in the operator class

information in pg_index. Both of these catalog entries can be accessed as part of the Relation data structure that is passed to all operations on the index.

Some of the flag columns of pg_am have nonobvious implications. The requirements of amcanunique are discussed in Section 55.5. The amcanmulticol flag asserts that the access method supports multicolumn indexes, while amoptionalkey asserts that it allows scans where no indexable restriction clause is given for the first index column. When amcanmulticol is false, amoptionalkey essentially says whether the access method supports full-index scans without any restriction clause. Access methods that support multiple index columns *must* support scans that omit restrictions on any or all of the columns after the first; however they are permitted to require some restriction to appear for the first index column, and this is signaled by setting amoptionalkey false. One reason that an index AM might set amoptionalkey false is if it doesn't index null values. Since most indexable operators are strict and hence cannot return true for null inputs, it is at first sight attractive to not store index entries for null values: they could never be returned by an index scan anyway. However, this argument fails when an index scan has no restriction clause for a given index column. In practice this means that indexes that have amoptionalkey true must index nulls, since the planner might decide to use such an index with no scan keys at all. A related restriction is that an index access method that supports multiple index columns *must* support indexing null values in columns after the first, because the planner will assume the index can be used for queries that do not restrict these columns. For example, consider an index on (a,b) and a query with WHERE a = 4. The system will assume the index can be used to scan for rows with a = 4, which is wrong if the index omits rows where b is null. It is, however, OK to omit rows where the first indexed column is null. An index access method that does index nulls may also set amsearchnulls, indicating that it supports IS NULL and IS NOT NULL clauses as search conditions.

55.2. Index Access Method Functions

The index construction and maintenance functions that an index access method must provide are:

```
IndexBuildResult *
ambuild (Relation heapRelation,
         Relation indexRelation,
         IndexInfo *indexInfo);
```

Build a new index. The index relation has been physically created, but is empty. It must be filled in with whatever fixed data the access method requires, plus entries for all tuples already existing in the table. Ordinarily the ambuild function will call IndexBuildHeapScan() to scan the table for existing tuples and compute the keys that need to be inserted into the index. The function must return a palloc'd struct containing statistics about the new index.

```
void
ambuildempty (Relation indexRelation);
```

Build an empty index, and write it to the initialization fork (INIT_FORKNUM) of the given relation. This method is called only for unlogged tables; the empty index written to the initialization fork will be copied over the main relation fork on each server restart.

```
bool
aminsert (Relation indexRelation,
          Datum *values,
          bool *isnull,
          ItemPointer heap_tid,
```

```
           Relation heapRelation,
           IndexUniqueCheck checkUnique);
```

Insert a new tuple into an existing index. The `values` and `isnull` arrays give the key values to be indexed, and `heap_tid` is the TID to be indexed. If the access method supports unique indexes (its `pg_am.amcanunique` flag is true) then `checkUnique` indicates the type of uniqueness check to perform. This varies depending on whether the unique constraint is deferrable; see Section 55.5 for details. Normally the access method only needs the `heapRelation` parameter when performing uniqueness checking (since then it will have to look into the heap to verify tuple liveness).

The function's Boolean result value is significant only when `checkUnique` is `UNIQUE_CHECK_PARTIAL`. In this case a TRUE result means the new entry is known unique, whereas FALSE means it might be non-unique (and a deferred uniqueness check must be scheduled). For other cases a constant FALSE result is recommended.

Some indexes might not index all tuples. If the tuple is not to be indexed, `aminsert` should just return without doing anything.

```
IndexBulkDeleteResult *
ambulkdelete (IndexVacuumInfo *info,
              IndexBulkDeleteResult *stats,
              IndexBulkDeleteCallback callback,
              void *callback_state);
```

Delete tuple(s) from the index. This is a "bulk delete" operation that is intended to be implemented by scanning the whole index and checking each entry to see if it should be deleted. The passed-in `callback` function must be called, in the style `callback(`*`TID`*`, callback_state) returns bool`, to determine whether any particular index entry, as identified by its referenced TID, is to be deleted. Must return either NULL or a palloc'd struct containing statistics about the effects of the deletion operation. It is OK to return NULL if no information needs to be passed on to `amvacuumcleanup`.

Because of limited `maintenance_work_mem`, `ambulkdelete` might need to be called more than once when many tuples are to be deleted. The `stats` argument is the result of the previous call for this index (it is NULL for the first call within a `VACUUM` operation). This allows the AM to accumulate statistics across the whole operation. Typically, `ambulkdelete` will modify and return the same struct if the passed `stats` is not null.

```
IndexBulkDeleteResult *
amvacuumcleanup (IndexVacuumInfo *info,
                 IndexBulkDeleteResult *stats);
```

Clean up after a `VACUUM` operation (zero or more `ambulkdelete` calls). This does not have to do anything beyond returning index statistics, but it might perform bulk cleanup such as reclaiming empty index pages. `stats` is whatever the last `ambulkdelete` call returned, or NULL if `ambulkdelete` was not called because no tuples needed to be deleted. If the result is not NULL it must be a palloc'd struct. The statistics it contains will be used to update `pg_class`, and will be reported by `VACUUM` if `VERBOSE` is given. It is OK to return NULL if the index was not changed at all during the `VACUUM` operation, but otherwise correct stats should be returned.

As of PostgreSQL 8.4, `amvacuumcleanup` will also be called at completion of an `ANALYZE` operation. In this case `stats` is always NULL and any return value will be ignored. This case can be distinguished by checking `info->analyze_only`. It is recommended that the access method do nothing except post-insert cleanup in such a call, and that only in an autovacuum worker process.

```
bool
amcanreturn (Relation indexRelation);
```

Check whether the index can support *index-only scans* by returning the indexed column values for an index entry in the form of an `IndexTuple`. Return TRUE if so, else FALSE. If the index AM can never support index-only scans (an example is hash, which stores only the hash values not the original data), it is sufficient to set its `amcanreturn` field to zero in `pg_am`.

```
void
amcostestimate (PlannerInfo *root,
                IndexPath *path,
                double loop_count,
                Cost *indexStartupCost,
                Cost *indexTotalCost,
                Selectivity *indexSelectivity,
                double *indexCorrelation);
```

Estimate the costs of an index scan. This function is described fully in Section 55.6, below.

```
bytea *
amoptions (ArrayType *reloptions,
           bool validate);
```

Parse and validate the reloptions array for an index. This is called only when a non-null reloptions array exists for the index. `reloptions` is a `text` array containing entries of the form *`name=value`*. The function should construct a `bytea` value, which will be copied into the `rd_options` field of the index's relcache entry. The data contents of the `bytea` value are open for the access method to define; most of the standard access methods use struct `StdRdOptions`. When `validate` is true, the function should report a suitable error message if any of the options are unrecognized or have invalid values; when `validate` is false, invalid entries should be silently ignored. (`validate` is false when loading options already stored in `pg_catalog`; an invalid entry could only be found if the access method has changed its rules for options, and in that case ignoring obsolete entries is appropriate.) It is OK to return NULL if default behavior is wanted.

The purpose of an index, of course, is to support scans for tuples matching an indexable `WHERE` condition, often called a *qualifier* or *scan key*. The semantics of index scanning are described more fully in Section 55.3, below. An index access method can support "plain" index scans, "bitmap" index scans, or both. The scan-related functions that an index access method must or may provide are:

```
IndexScanDesc
ambeginscan (Relation indexRelation,
             int nkeys,
             int norderbys);
```

Prepare for an index scan. The `nkeys` and `norderbys` parameters indicate the number of quals and ordering operators that will be used in the scan; these may be useful for space allocation purposes. Note that the actual values of the scan keys aren't provided yet. The result must be a palloc'd struct. For implementation reasons the index access method *must* create this struct by calling `RelationGetIndexScan()`. In most cases `ambeginscan` does little beyond making that call and perhaps acquiring locks; the interesting parts of index-scan startup are in `amrescan`.

```
void
amrescan (IndexScanDesc scan,
          ScanKey keys,
```

```
           int nkeys,
           ScanKey orderbys,
           int norderbys);
```

Start or restart an index scan, possibly with new scan keys. (To restart using previously-passed keys, NULL is passed for `keys` and/or `orderbys`.) Note that it is not allowed for the number of keys or order-by operators to be larger than what was passed to `ambeginscan`. In practice the restart feature is used when a new outer tuple is selected by a nested-loop join and so a new key comparison value is needed, but the scan key structure remains the same.

```
boolean
amgettuple (IndexScanDesc scan,
            ScanDirection direction);
```

Fetch the next tuple in the given scan, moving in the given direction (forward or backward in the index). Returns TRUE if a tuple was obtained, FALSE if no matching tuples remain. In the TRUE case the tuple TID is stored into the `scan` structure. Note that "success" means only that the index contains an entry that matches the scan keys, not that the tuple necessarily still exists in the heap or will pass the caller's snapshot test. On success, `amgettuple` must also set `scan->xs_recheck` to TRUE or FALSE. FALSE means it is certain that the index entry matches the scan keys. TRUE means this is not certain, and the conditions represented by the scan keys must be rechecked against the heap tuple after fetching it. This provision supports "lossy" index operators. Note that rechecking will extend only to the scan conditions; a partial index predicate (if any) is never rechecked by `amgettuple` callers.

If the index supports index-only scans (i.e., `amcanreturn` returns TRUE for it), then on success the AM must also check `scan->xs_want_itup`, and if that is true it must return the original indexed data for the index entry, in the form of an `IndexTuple` pointer stored at `scan->xs_itup`, with tuple descriptor `scan->xs_itupdesc`. (Management of the data referenced by the pointer is the access method's responsibility. The data must remain good at least until the next `amgettuple`, `amrescan`, or `amendscan` call for the scan.)

The `amgettuple` function need only be provided if the access method supports "plain" index scans. If it doesn't, the `amgettuple` field in its `pg_am` row must be set to zero.

```
int64
amgetbitmap (IndexScanDesc scan,
             TIDBitmap *tbm);
```

Fetch all tuples in the given scan and add them to the caller-supplied `TIDBitmap` (that is, OR the set of tuple IDs into whatever set is already in the bitmap). The number of tuples fetched is returned (this might be just an approximate count, for instance some AMs do not detect duplicates). While inserting tuple IDs into the bitmap, `amgetbitmap` can indicate that rechecking of the scan conditions is required for specific tuple IDs. This is analogous to the `xs_recheck` output parameter of `amgettuple`. Note: in the current implementation, support for this feature is conflated with support for lossy storage of the bitmap itself, and therefore callers recheck both the scan conditions and the partial index predicate (if any) for recheckable tuples. That might not always be true, however. `amgetbitmap` and `amgettuple` cannot be used in the same index scan; there are other restrictions too when using `amgetbitmap`, as explained in Section 55.3.

The `amgetbitmap` function need only be provided if the access method supports "bitmap" index scans. If it doesn't, the `amgetbitmap` field in its `pg_am` row must be set to zero.

```
void
amendscan (IndexScanDesc scan);
```

End a scan and release resources. The `scan` struct itself should not be freed, but any locks or pins taken internally by the access method must be released.

```
void
ammarkpos (IndexScanDesc scan);
```

Mark current scan position. The access method need only support one remembered scan position per scan.

```
void
amrestrpos (IndexScanDesc scan);
```

Restore the scan to the most recently marked position.

By convention, the `pg_proc` entry for an index access method function should show the correct number of arguments, but declare them all as type `internal` (since most of the arguments have types that are not known to SQL, and we don't want users calling the functions directly anyway). The return type is declared as `void`, `internal`, or `boolean` as appropriate. The only exception is `amoptions`, which should be correctly declared as taking `text[]` and `bool` and returning `bytea`. This provision allows client code to execute `amoptions` to test validity of options settings.

55.3. Index Scanning

In an index scan, the index access method is responsible for regurgitating the TIDs of all the tuples it has been told about that match the *scan keys*. The access method is *not* involved in actually fetching those tuples from the index's parent table, nor in determining whether they pass the scan's time qualification test or other conditions.

A scan key is the internal representation of a `WHERE` clause of the form *`index_key operator constant`*, where the index key is one of the columns of the index and the operator is one of the members of the operator family associated with that index column. An index scan has zero or more scan keys, which are implicitly ANDed — the returned tuples are expected to satisfy all the indicated conditions.

The access method can report that the index is *lossy*, or requires rechecks, for a particular query. This implies that the index scan will return all the entries that pass the scan key, plus possibly additional entries that do not. The core system's index-scan machinery will then apply the index conditions again to the heap tuple to verify whether or not it really should be selected. If the recheck option is not specified, the index scan must return exactly the set of matching entries.

Note that it is entirely up to the access method to ensure that it correctly finds all and only the entries passing all the given scan keys. Also, the core system will simply hand off all the `WHERE` clauses that match the index keys and operator families, without any semantic analysis to determine whether they are redundant or contradictory. As an example, given `WHERE x > 4 AND x > 14` where `x` is a b-tree indexed column, it is left to the b-tree `amrescan` function to realize that the first scan key is redundant and can be discarded. The extent of preprocessing needed during `amrescan` will depend on the extent to which the index access method needs to reduce the scan keys to a "normalized" form.

Some access methods return index entries in a well-defined order, others do not. There are actually two different ways that an access method can support sorted output:

- Access methods that always return entries in the natural ordering of their data (such as btree) should set `pg_am.amcanorder` to true. Currently, such access methods must use btree-compatible strategy numbers for their equality and ordering operators.

- Access methods that support ordering operators should set pg_am.amcanorderbyop to true. This indicates that the index is capable of returning entries in an order satisfying ORDER BY *index_key operator constant*. Scan modifiers of that form can be passed to amrescan as described previously.

The amgettuple function has a direction argument, which can be either ForwardScanDirection (the normal case) or BackwardScanDirection. If the first call after amrescan specifies BackwardScanDirection, then the set of matching index entries is to be scanned back-to-front rather than in the normal front-to-back direction, so amgettuple must return the last matching tuple in the index, rather than the first one as it normally would. (This will only occur for access methods that set amcanorder to true.) After the first call, amgettuple must be prepared to advance the scan in either direction from the most recently returned entry. (But if pg_am.amcanbackward is false, all subsequent calls will have the same direction as the first one.)

Access methods that support ordered scans must support "marking" a position in a scan and later returning to the marked position. The same position might be restored multiple times. However, only one position need be remembered per scan; a new ammarkpos call overrides the previously marked position. An access method that does not support ordered scans should still provide mark and restore functions in pg_am, but it is sufficient to have them throw errors if called.

Both the scan position and the mark position (if any) must be maintained consistently in the face of concurrent insertions or deletions in the index. It is OK if a freshly-inserted entry is not returned by a scan that would have found the entry if it had existed when the scan started, or for the scan to return such an entry upon rescanning or backing up even though it had not been returned the first time through. Similarly, a concurrent delete might or might not be reflected in the results of a scan. What is important is that insertions or deletions not cause the scan to miss or multiply return entries that were not themselves being inserted or deleted.

If the index stores the original indexed data values (and not some lossy representation of them), it is useful to support index-only scans, in which the index returns the actual data not just the TID of the heap tuple. This will only work if the visibility map shows that the TID is on an all-visible page; else the heap tuple must be visited anyway to check MVCC visibility. But that is no concern of the access method's.

Instead of using amgettuple, an index scan can be done with amgetbitmap to fetch all tuples in one call. This can be noticeably more efficient than amgettuple because it allows avoiding lock/unlock cycles within the access method. In principle amgetbitmap should have the same effects as repeated amgettuple calls, but we impose several restrictions to simplify matters. First of all, amgetbitmap returns all tuples at once and marking or restoring scan positions isn't supported. Secondly, the tuples are returned in a bitmap which doesn't have any specific ordering, which is why amgetbitmap doesn't take a direction argument. (Ordering operators will never be supplied for such a scan, either.) Also, there is no provision for index-only scans with amgetbitmap, since there is no way to return the contents of index tuples. Finally, amgetbitmap does not guarantee any locking of the returned tuples, with implications spelled out in Section 55.4.

Note that it is permitted for an access method to implement only amgetbitmap and not amgettuple, or vice versa, if its internal implementation is unsuited to one API or the other.

55.4. Index Locking Considerations

Index access methods must handle concurrent updates of the index by multiple processes. The core PostgreSQL system obtains AccessShareLock on the index during an index scan, and

RowExclusiveLock when updating the index (including plain VACUUM). Since these lock types do not conflict, the access method is responsible for handling any fine-grained locking it might need. An exclusive lock on the index as a whole will be taken only during index creation, destruction, or REINDEX.

Building an index type that supports concurrent updates usually requires extensive and subtle analysis of the required behavior. For the b-tree and hash index types, you can read about the design decisions involved in src/backend/access/nbtree/README and src/backend/access/hash/README.

Aside from the index's own internal consistency requirements, concurrent updates create issues about consistency between the parent table (the *heap*) and the index. Because PostgreSQL separates accesses and updates of the heap from those of the index, there are windows in which the index might be inconsistent with the heap. We handle this problem with the following rules:

- A new heap entry is made before making its index entries. (Therefore a concurrent index scan is likely to fail to see the heap entry. This is okay because the index reader would be uninterested in an uncommitted row anyway. But see Section 55.5.)
- When a heap entry is to be deleted (by VACUUM), all its index entries must be removed first.
- An index scan must maintain a pin on the index page holding the item last returned by amgettuple, and ambulkdelete cannot delete entries from pages that are pinned by other backends. The need for this rule is explained below.

Without the third rule, it is possible for an index reader to see an index entry just before it is removed by VACUUM, and then to arrive at the corresponding heap entry after that was removed by VACUUM. This creates no serious problems if that item number is still unused when the reader reaches it, since an empty item slot will be ignored by heap_fetch(). But what if a third backend has already reused the item slot for something else? When using an MVCC-compliant snapshot, there is no problem because the new occupant of the slot is certain to be too new to pass the snapshot test. However, with a non-MVCC-compliant snapshot (such as SnapshotAny), it would be possible to accept and return a row that does not in fact match the scan keys. We could defend against this scenario by requiring the scan keys to be rechecked against the heap row in all cases, but that is too expensive. Instead, we use a pin on an index page as a proxy to indicate that the reader might still be "in flight" from the index entry to the matching heap entry. Making ambulkdelete block on such a pin ensures that VACUUM cannot delete the heap entry before the reader is done with it. This solution costs little in run time, and adds blocking overhead only in the rare cases where there actually is a conflict.

This solution requires that index scans be "synchronous": we have to fetch each heap tuple immediately after scanning the corresponding index entry. This is expensive for a number of reasons. An "asynchronous" scan in which we collect many TIDs from the index, and only visit the heap tuples sometime later, requires much less index locking overhead and can allow a more efficient heap access pattern. Per the above analysis, we must use the synchronous approach for non-MVCC-compliant snapshots, but an asynchronous scan is workable for a query using an MVCC snapshot.

In an amgetbitmap index scan, the access method does not keep an index pin on any of the returned tuples. Therefore it is only safe to use such scans with MVCC-compliant snapshots.

When the ampredlocks flag is not set, any scan using that index access method within a serializable transaction will acquire a nonblocking predicate lock on the full index. This will generate a read-write conflict with the insert of any tuple into that index by a concurrent serializable transaction. If certain patterns of read-write conflicts are detected among a set of concurrent serializable transactions, one of those transactions may be canceled to protect data integrity. When the flag is set, it indicates that the index access method implements finer-grained predicate locking, which will tend to reduce the frequency of such transaction cancellations.

55.5. Index Uniqueness Checks

PostgreSQL enforces SQL uniqueness constraints using *unique indexes*, which are indexes that disallow multiple entries with identical keys. An access method that supports this feature sets `pg_am.amcanunique` true. (At present, only b-tree supports it.)

Because of MVCC, it is always necessary to allow duplicate entries to exist physically in an index: the entries might refer to successive versions of a single logical row. The behavior we actually want to enforce is that no MVCC snapshot could include two rows with equal index keys. This breaks down into the following cases that must be checked when inserting a new row into a unique index:

- If a conflicting valid row has been deleted by the current transaction, it's okay. (In particular, since an UPDATE always deletes the old row version before inserting the new version, this will allow an UPDATE on a row without changing the key.)
- If a conflicting row has been inserted by an as-yet-uncommitted transaction, the would-be inserter must wait to see if that transaction commits. If it rolls back then there is no conflict. If it commits without deleting the conflicting row again, there is a uniqueness violation. (In practice we just wait for the other transaction to end and then redo the visibility check in toto.)
- Similarly, if a conflicting valid row has been deleted by an as-yet-uncommitted transaction, the would-be inserter must wait for that transaction to commit or abort, and then repeat the test.

Furthermore, immediately before reporting a uniqueness violation according to the above rules, the access method must recheck the liveness of the row being inserted. If it is committed dead then no violation should be reported. (This case cannot occur during the ordinary scenario of inserting a row that's just been created by the current transaction. It can happen during `CREATE UNIQUE INDEX CONCURRENTLY`, however.)

We require the index access method to apply these tests itself, which means that it must reach into the heap to check the commit status of any row that is shown to have a duplicate key according to the index contents. This is without a doubt ugly and non-modular, but it saves redundant work: if we did a separate probe then the index lookup for a conflicting row would be essentially repeated while finding the place to insert the new row's index entry. What's more, there is no obvious way to avoid race conditions unless the conflict check is an integral part of insertion of the new index entry.

If the unique constraint is deferrable, there is additional complexity: we need to be able to insert an index entry for a new row, but defer any uniqueness-violation error until end of statement or even later. To avoid unnecessary repeat searches of the index, the index access method should do a preliminary uniqueness check during the initial insertion. If this shows that there is definitely no conflicting live tuple, we are done. Otherwise, we schedule a recheck to occur when it is time to enforce the constraint. If, at the time of the recheck, both the inserted tuple and some other tuple with the same key are live, then the error must be reported. (Note that for this purpose, "live" actually means "any tuple in the index entry's HOT chain is live".) To implement this, the `aminsert` function is passed a `checkUnique` parameter having one of the following values:

- `UNIQUE_CHECK_NO` indicates that no uniqueness checking should be done (this is not a unique index).
- `UNIQUE_CHECK_YES` indicates that this is a non-deferrable unique index, and the uniqueness check must be done immediately, as described above.
- `UNIQUE_CHECK_PARTIAL` indicates that the unique constraint is deferrable. PostgreSQL will use this mode to insert each row's index entry. The access method must allow duplicate entries into the

index, and report any potential duplicates by returning FALSE from `aminsert`. For each row for which FALSE is returned, a deferred recheck will be scheduled.

The access method must identify any rows which might violate the unique constraint, but it is not an error for it to report false positives. This allows the check to be done without waiting for other transactions to finish; conflicts reported here are not treated as errors and will be rechecked later, by which time they may no longer be conflicts.

- `UNIQUE_CHECK_EXISTING` indicates that this is a deferred recheck of a row that was reported as a potential uniqueness violation. Although this is implemented by calling `aminsert`, the access method must *not* insert a new index entry in this case. The index entry is already present. Rather, the access method must check to see if there is another live index entry. If so, and if the target row is also still live, report error.

  It is recommended that in a `UNIQUE_CHECK_EXISTING` call, the access method further verify that the target row actually does have an existing entry in the index, and report error if not. This is a good idea because the index tuple values passed to `aminsert` will have been recomputed. If the index definition involves functions that are not really immutable, we might be checking the wrong area of the index. Checking that the target row is found in the recheck verifies that we are scanning for the same tuple values as were used in the original insertion.

55.6. Index Cost Estimation Functions

The `amcostestimate` function is given information describing a possible index scan, including lists of WHERE and ORDER BY clauses that have been determined to be usable with the index. It must return estimates of the cost of accessing the index and the selectivity of the WHERE clauses (that is, the fraction of parent-table rows that will be retrieved during the index scan). For simple cases, nearly all the work of the cost estimator can be done by calling standard routines in the optimizer; the point of having an `amcostestimate` function is to allow index access methods to provide index-type-specific knowledge, in case it is possible to improve on the standard estimates.

Each `amcostestimate` function must have the signature:

```
void
amcostestimate (PlannerInfo *root,
                IndexPath *path,
                double loop_count,
                Cost *indexStartupCost,
                Cost *indexTotalCost,
                Selectivity *indexSelectivity,
                double *indexCorrelation);
```

The first three parameters are inputs:

`root`

The planner's information about the query being processed.

`path`

The index access path being considered. All fields except cost and selectivity values are valid.

`loop_count`

The number of repetitions of the index scan that should be factored into the cost estimates. This will typically be greater than one when considering a parameterized scan for use in the inside of a nestloop join. Note that the cost estimates should still be for just one scan; a larger `loop_count` means that it may be appropriate to allow for some caching effects across multiple scans.

The last four parameters are pass-by-reference outputs:

`*indexStartupCost`

Set to cost of index start-up processing

`*indexTotalCost`

Set to total cost of index processing

`*indexSelectivity`

Set to index selectivity

`*indexCorrelation`

Set to correlation coefficient between index scan order and underlying table's order

Note that cost estimate functions must be written in C, not in SQL or any available procedural language, because they must access internal data structures of the planner/optimizer.

The index access costs should be computed using the parameters used by `src/backend/optimizer/path/costsize.c`: a sequential disk block fetch has cost `seq_page_cost`, a nonsequential fetch has cost `random_page_cost`, and the cost of processing one index row should usually be taken as `cpu_index_tuple_cost`. In addition, an appropriate multiple of `cpu_operator_cost` should be charged for any comparison operators invoked during index processing (especially evaluation of the indexquals themselves).

The access costs should include all disk and CPU costs associated with scanning the index itself, but *not* the costs of retrieving or processing the parent-table rows that are identified by the index.

The "start-up cost" is the part of the total scan cost that must be expended before we can begin to fetch the first row. For most indexes this can be taken as zero, but an index type with a high start-up cost might want to set it nonzero.

The `indexSelectivity` should be set to the estimated fraction of the parent table rows that will be retrieved during the index scan. In the case of a lossy query, this will typically be higher than the fraction of rows that actually pass the given qual conditions.

The `indexCorrelation` should be set to the correlation (ranging between -1.0 and 1.0) between the index order and the table order. This is used to adjust the estimate for the cost of fetching rows from the parent table.

When `loop_count` is greater than one, the returned numbers should be averages expected for any one scan of the index.

Cost Estimation

A typical cost estimator will proceed as follows:

1. Estimate and return the fraction of parent-table rows that will be visited based on the given qual conditions. In the absence of any index-type-specific knowledge, use the standard optimizer function `clauselist_selectivity()`:

```
*indexSelectivity = clauselist_selectivity(root, path->indexquals,
                                           path->indexinfo->rel->relid,
                                           JOIN_INNER, NULL);
```

2. Estimate the number of index rows that will be visited during the scan. For many index types this is the same as `indexSelectivity` times the number of rows in the index, but it might be more. (Note that the index's size in pages and rows is available from the `path->indexinfo` struct.)

3. Estimate the number of index pages that will be retrieved during the scan. This might be just `indexSelectivity` times the index's size in pages.

4. Compute the index access cost. A generic estimator might do this:

```
/*
 * Our generic assumption is that the index pages will be read
 * sequentially, so they cost seq_page_cost each, not random_page_cost.
 * Also, we charge for evaluation of the indexquals at each index row.
 * All the costs are assumed to be paid incrementally during the scan.
 */
cost_qual_eval(&index_qual_cost, path->indexquals, root);
*indexStartupCost = index_qual_cost.startup;
*indexTotalCost = seq_page_cost * numIndexPages +
    (cpu_index_tuple_cost + index_qual_cost.per_tuple) * numIndexTuples;
```

   However, the above does not account for amortization of index reads across repeated index scans.

5. Estimate the index correlation. For a simple ordered index on a single field, this can be retrieved from pg_statistic. If the correlation is not known, the conservative estimate is zero (no correlation).

Examples of cost estimator functions can be found in `src/backend/utils/adt/selfuncs.c`.

Chapter 56. GiST Indexes

56.1. Introduction

GiST stands for Generalized Search Tree. It is a balanced, tree-structured access method, that acts as a base template in which to implement arbitrary indexing schemes. B-trees, R-trees and many other indexing schemes can be implemented in GiST.

One advantage of GiST is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert.

Some of the information here is derived from the University of California at Berkeley's GiST Indexing Project web site[1] and Marcel Kornacker's thesis, Access Methods for Next-Generation Database Systems[2]. The GiST implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov, and there is more information on their web site[3].

56.2. Built-in Operator Classes

The core PostgreSQL distribution includes the GiST operator classes shown in Table 56-1. (Some of the optional modules described in Appendix F provide additional GiST operator classes.)

Table 56-1. Built-in GiST Operator Classes

Name	Indexed Data Type	Indexable Operators	Ordering Operators
box_ops	box	&& &> &< &<| >> << <<| <@ @> @ |&> |>> ~ ~=	
circle_ops	circle	&& &> &< &<| >> << <<| <@ @> @ |&> |>> ~ ~=	
inet_ops	inet, cidr	&& >> >>= > >= <> << <<= < <= =	
point_ops	point	>> >^ << <@ <@ <@ <^ ~=	<->
poly_ops	polygon	&& &> &< &<| >> << <<| <@ @> @ |&> |>> ~ ~=	
range_ops	any range type	&& &> &< >> << <@ -|- = @> @>	
tsquery_ops	tsquery	<@ @>	
tsvector_ops	tsvector	@@	

1. http://gist.cs.berkeley.edu/
2. http://www.sai.msu.su/~megera/postgres/gist/papers/concurrency/access-methods-for-next-generation.pdf.gz
3. http://www.sai.msu.su/~megera/postgres/gist/

For historical reasons, the `inet_ops` operator class is not the default class for types `inet` and `cidr`. To use it, mention the class name in `CREATE INDEX`, for example

```
CREATE INDEX ON my_table USING gist (my_inet_column inet_ops);
```

56.3. Extensibility

Traditionally, implementing a new index access method meant a lot of difficult work. It was necessary to understand the inner workings of the database, such as the lock manager and Write-Ahead Log. The GiST interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GiST layer itself takes care of concurrency, logging and searching the tree structure.

This extensibility should not be confused with the extensibility of the other standard search trees in terms of the data they can handle. For example, PostgreSQL supports extensible B-trees and hash indexes. That means that you can use PostgreSQL to build a B-tree or hash over any data type you want. But B-trees only support range predicates (<, =, >), and hash indexes only support equality queries.

So if you index, say, an image collection with a PostgreSQL B-tree, you can only issue queries such as "is imagex equal to imagey", "is imagex less than imagey" and "is imagex greater than imagey". Depending on how you define "equals", "less than" and "greater than" in this context, this could be useful. However, by using a GiST based index, you could create ways to ask domain-specific questions, perhaps "find all images of horses" or "find all over-exposed images".

All it takes to get a GiST access method up and running is to implement several user-defined methods, which define the behavior of keys in the tree. Of course these methods have to be pretty fancy to support fancy queries, but for all the standard queries (B-trees, R-trees, etc.) they're relatively straightforward. In short, GiST combines extensibility along with generality, code reuse, and a clean interface.

There are seven methods that an index operator class for GiST must provide, and an eighth that is optional. Correctness of the index is ensured by proper implementation of the `same`, `consistent` and `union` methods, while efficiency (size and speed) of the index will depend on the `penalty` and `picksplit` methods. The remaining two basic methods are `compress` and `decompress`, which allow an index to have internal tree data of a different type than the data it indexes. The leaves are to be of the indexed data type, while the other tree nodes can be of any C struct (but you still have to follow PostgreSQL data type rules here, see about `varlena` for variable sized data). If the tree's internal data type exists at the SQL level, the `STORAGE` option of the `CREATE OPERATOR CLASS` command can be used. The optional eighth method is `distance`, which is needed if the operator class wishes to support ordered scans (nearest-neighbor searches).

`consistent`

> Given an index entry `p` and a query value `q`, this function determines whether the index entry is "consistent" with the query; that is, could the predicate "*`indexed_column indexable_operator q`*" be true for any row represented by the index entry? For a leaf index entry this is equivalent to testing the indexable condition, while for an internal tree node this determines whether it is necessary to scan the subtree of the index represented by the tree node. When the result is `true`, a `recheck` flag must also be returned. This indicates whether the predicate is certainly true or only possibly true. If `recheck` = `false` then the index has tested the predicate condition exactly, whereas if `recheck` = `true` the row is only a candidate match.

In that case the system will automatically evaluate the *indexable_operator* against the actual row value to see if it is really a match. This convention allows GiST to support both lossless and lossy index structures.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_consistent(internal, data_type, smallint, oid, internal
RETURNS bool
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_consistent(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_consistent);

Datum
my_consistent(PG_FUNCTION_ARGS)
{
    GISTENTRY  *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type  *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber) PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    bool       *recheck = (bool *) PG_GETARG_POINTER(4);
    data_type  *key = DatumGetDataType(entry->key);
    bool        retval;

    /*
     * determine return value as a function of strategy, key and query.
     *
     * Use GIST_LEAF(entry) to know where you're called in the index tree,
     * which comes handy when supporting the = operator for example (you could
     * check for non empty union() in non-leaf nodes and equality in leaf
     * nodes).
     */

    *recheck = true;        /* or false if check is exact */

    PG_RETURN_BOOL(retval);
}
```

Here, `key` is an element in the index and `query` the value being looked up in the index. The `StrategyNumber` parameter indicates which operator of your operator class is being applied — it matches one of the operator numbers in the `CREATE OPERATOR CLASS` command. Depending on what operators you have included in the class, the data type of `query` could vary with the operator, but the above skeleton assumes it doesn't.

`union`

This method consolidates information in the tree. Given a set of entries, this function generates a new index entry that represents all the given entries.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_union(internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_union(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_union);
```

```
Datum
my_union(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *) PG_GETARG_POINTER(0);
    GISTENTRY  *ent = entryvec->vector;
    data_type  *out,
               *tmp,
               *old;
    int         numranges,
                i = 0;

    numranges = entryvec->n;
    tmp = DatumGetDataType(ent[0].key);
    out = tmp;

    if (numranges == 1)
    {
        out = data_type_deep_copy(tmp);

        PG_RETURN_DATA_TYPE_P(out);
    }

    for (i = 1; i < numranges; i++)
    {
        old = out;
        tmp = DatumGetDataType(ent[i].key);
        out = my_union_implementation(out, tmp);
    }

    PG_RETURN_DATA_TYPE_P(out);
}
```

As you can see, in this skeleton we're dealing with a data type where `union(X, Y, Z) = union(union(X, Y), Z)`. It's easy enough to support data types where this is not the case, by implementing the proper union algorithm in this GiST support method.

The `union` implementation function should return a pointer to newly `palloc()`ed memory. You can't just return whatever the input is.

`compress`

Converts the data item into a format suitable for physical storage in an index page.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_compress(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_compress(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_compress);

Datum
my_compress(PG_FUNCTION_ARGS)
{
    GISTENTRY  *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY  *retval;
```

```
    if (entry->leafkey)
    {
        /* replace entry->key with a compressed version */
        compressed_data_type *compressed_data = palloc(sizeof(compressed_data_type));

        /* fill *compressed_data from entry->key ... */

        retval = palloc(sizeof(GISTENTRY));
        gistentryinit(*retval, PointerGetDatum(compressed_data),
                      entry->rel, entry->page, entry->offset, FALSE);
    }
    else
    {
        /* typically we needn't do anything with non-leaf entries */
        retval = entry;
    }

    PG_RETURN_POINTER(retval);
}
```

You have to adapt *compressed_data_type* to the specific type you're converting to in order to compress your leaf nodes, of course.

Depending on your needs, you could also need to care about compressing `NULL` values in there, storing for example `(Datum) 0` like `gist_circle_compress` does.

`decompress`

The reverse of the `compress` method. Converts the index representation of the data item into a format that can be manipulated by the database.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_decompress(internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_decompress(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_decompress);

Datum
my_decompress(PG_FUNCTION_ARGS)
{
    PG_RETURN_POINTER(PG_GETARG_POINTER(0));
}
```

The above skeleton is suitable for the case where no decompression is needed.

`penalty`

Returns a value indicating the "cost" of inserting the new entry into a particular branch of the tree. Items will be inserted down the path of least `penalty` in the tree. Values returned by `penalty` should be non-negative. If a negative value is returned, it will be treated as zero.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_penalty(internal, internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;  -- in some cases penalty functions need not be strict
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_penalty(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_penalty);

Datum
my_penalty(PG_FUNCTION_ARGS)
{
    GISTENTRY  *origentry = (GISTENTRY *) PG_GETARG_POINTER(0);
    GISTENTRY  *newentry = (GISTENTRY *) PG_GETARG_POINTER(1);
    float      *penalty = (float *) PG_GETARG_POINTER(2);
    data_type  *orig = DatumGetDataType(origentry->key);
    data_type  *new = DatumGetDataType(newentry->key);

    *penalty = my_penalty_implementation(orig, new);
    PG_RETURN_POINTER(penalty);
}
```

The `penalty` function is crucial to good performance of the index. It'll get used at insertion time to determine which branch to follow when choosing where to add the new entry in the tree. At query time, the more balanced the index, the quicker the lookup.

`picksplit`

When an index page split is necessary, this function decides which entries on the page are to stay on the old page, and which are to move to the new page.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_picksplit(internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_picksplit(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_picksplit);

Datum
my_picksplit(PG_FUNCTION_ARGS)
{
    GistEntryVector *entryvec = (GistEntryVector *) PG_GETARG_POINTER(0);
    OffsetNumber maxoff = entryvec->n - 1;
    GISTENTRY  *ent = entryvec->vector;
    GIST_SPLITVEC *v = (GIST_SPLITVEC *) PG_GETARG_POINTER(1);
    int         i,
                nbytes;
    OffsetNumber *left,
               *right;
    data_type  *tmp_union;
    data_type  *unionL;
    data_type  *unionR;
    GISTENTRY **raw_entryvec;

    maxoff = entryvec->n - 1;
    nbytes = (maxoff + 1) * sizeof(OffsetNumber);

    v->spl_left = (OffsetNumber *) palloc(nbytes);
    left = v->spl_left;
    v->spl_nleft = 0;
```

```
    v->spl_right = (OffsetNumber *) palloc(nbytes);
    right = v->spl_right;
    v->spl_nright = 0;

    unionL = NULL;
    unionR = NULL;

    /* Initialize the raw entry vector. */
    raw_entryvec = (GISTENTRY **) malloc(entryvec->n * sizeof(void *));
    for (i = FirstOffsetNumber; i <= maxoff; i = OffsetNumberNext(i))
        raw_entryvec[i] = &(entryvec->vector[i]);

    for (i = FirstOffsetNumber; i <= maxoff; i = OffsetNumberNext(i))
    {
        int         real_index = raw_entryvec[i] - entryvec->vector;

        tmp_union = DatumGetDataType(entryvec->vector[real_index].key);
        Assert(tmp_union != NULL);

        /*
         * Choose where to put the index entries and update unionL and unionR
         * accordingly. Append the entries to either v_spl_left or
         * v_spl_right, and care about the counters.
         */

        if (my_choice_is_left(unionL, curl, unionR, curr))
        {
            if (unionL == NULL)
                unionL = tmp_union;
            else
                unionL = my_union_implementation(unionL, tmp_union);

            *left = real_index;
            ++left;
            ++(v->spl_nleft);
        }
        else
        {
            /*
             * Same on the right
             */
        }
    }

    v->spl_ldatum = DataTypeGetDatum(unionL);
    v->spl_rdatum = DataTypeGetDatum(unionR);
    PG_RETURN_POINTER(v);
}
```

Like `penalty`, the `picksplit` function is crucial to good performance of the index. Designing suitable `penalty` and `picksplit` implementations is where the challenge of implementing well-performing GiST indexes lies.

`same`

Returns true if two index entries are identical, false otherwise.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_same(internal, internal, internal)
RETURNS internal
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_same(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_same);

Datum
my_same(PG_FUNCTION_ARGS)
{
    prefix_range *v1 = PG_GETARG_PREFIX_RANGE_P(0);
    prefix_range *v2 = PG_GETARG_PREFIX_RANGE_P(1);
    bool       *result = (bool *) PG_GETARG_POINTER(2);

    *result = my_eq(v1, v2);
    PG_RETURN_POINTER(result);
}
```

For historical reasons, the `same` function doesn't just return a Boolean result; instead it has to store the flag at the location indicated by the third argument.

`distance`

Given an index entry `p` and a query value `q`, this function determines the index entry's "distance" from the query value. This function must be supplied if the operator class contains any ordering operators. A query using the ordering operator will be implemented by returning index entries with the smallest "distance" values first, so the results must be consistent with the operator's semantics. For a leaf index entry the result just represents the distance to the index entry; for an internal tree node, the result must be the smallest distance that any child entry could have.

The SQL declaration of the function must look like this:

```
CREATE OR REPLACE FUNCTION my_distance(internal, data_type, smallint, oid)
RETURNS float8
AS 'MODULE_PATHNAME'
LANGUAGE C STRICT;
```

And the matching code in the C module could then follow this skeleton:

```
Datum       my_distance(PG_FUNCTION_ARGS);
PG_FUNCTION_INFO_V1(my_distance);

Datum
my_distance(PG_FUNCTION_ARGS)
{
    GISTENTRY  *entry = (GISTENTRY *) PG_GETARG_POINTER(0);
    data_type  *query = PG_GETARG_DATA_TYPE_P(1);
    StrategyNumber strategy = (StrategyNumber) PG_GETARG_UINT16(2);
    /* Oid subtype = PG_GETARG_OID(3); */
    data_type  *key = DatumGetDataType(entry->key);
    double      retval;

    /*
     * determine return value as a function of strategy, key and query.
     */
```

```
    PG_RETURN_FLOAT8(retval);
}
```

The arguments to the `distance` function are identical to the arguments of the `consistent` function, except that no recheck flag is used. The distance to a leaf index entry must always be determined exactly, since there is no way to re-order the tuples once they are returned. Some approximation is allowed when determining the distance to an internal tree node, so long as the result is never greater than any child's actual distance. Thus, for example, distance to a bounding box is usually sufficient in geometric applications. The result value can be any finite `float8` value. (Infinity and minus infinity are used internally to handle cases such as nulls, so it is not recommended that `distance` functions return these values.)

All the GiST support methods are normally called in short-lived memory contexts; that is, `CurrentMemoryContext` will get reset after each tuple is processed. It is therefore not very important to worry about pfree'ing everything you palloc. However, in some cases it's useful for a support method to cache data across repeated calls. To do that, allocate the longer-lived data in `fcinfo->flinfo->fn_mcxt`, and keep a pointer to it in `fcinfo->flinfo->fn_extra`. Such data will survive for the life of the index operation (e.g., a single GiST index scan, index build, or index tuple insertion). Be careful to pfree the previous value when replacing a `fn_extra` value, or the leak will accumulate for the duration of the operation.

56.4. Implementation

56.4.1. GiST buffering build

Building large GiST indexes by simply inserting all the tuples tends to be slow, because if the index tuples are scattered across the index and the index is large enough to not fit in cache, the insertions need to perform a lot of random I/O. Beginning in version 9.2, PostgreSQL supports a more efficient method to build GiST indexes based on buffering, which can dramatically reduce the number of random I/Os needed for non-ordered data sets. For well-ordered data sets the benefit is smaller or non-existent, because only a small number of pages receive new tuples at a time, and those pages fit in cache even if the index as whole does not.

However, buffering index build needs to call the `penalty` function more often, which consumes some extra CPU resources. Also, the buffers used in the buffering build need temporary disk space, up to the size of the resulting index. Buffering can also influence the quality of the resulting index, in both positive and negative directions. That influence depends on various factors, like the distribution of the input data and the operator class implementation.

By default, a GiST index build switches to the buffering method when the index size reaches effective_cache_size. It can be manually turned on or off by the `BUFFERING` parameter to the CREATE INDEX command. The default behavior is good for most cases, but turning buffering off might speed up the build somewhat if the input data is ordered.

56.5. Examples

The PostgreSQL source distribution includes several examples of index methods implemented using GiST. The core system currently provides text search support (indexing for `tsvector` and `tsquery`) as well as R-Tree equivalent functionality for some of the built-in geometric data types

(see `src/backend/access/gist/gistproc.c`). The following `contrib` modules also contain GiST operator classes:

`btree_gist`

B-tree equivalent functionality for several data types

`cube`

Indexing for multidimensional cubes

`hstore`

Module for storing (key, value) pairs

`intarray`

RD-Tree for one-dimensional array of int4 values

`ltree`

Indexing for tree-like structures

`pg_trgm`

Text similarity using trigram matching

`seg`

Indexing for "float ranges"

Chapter 57. SP-GiST Indexes

57.1. Introduction

SP-GiST is an abbreviation for space-partitioned GiST. SP-GiST supports partitioned search trees, which facilitate development of a wide range of different non-balanced data structures, such as quad-trees, k-d trees, and radix trees (tries). The common feature of these structures is that they repeatedly divide the search space into partitions that need not be of equal size. Searches that are well matched to the partitioning rule can be very fast.

These popular data structures were originally developed for in-memory usage. In main memory, they are usually designed as a set of dynamically allocated nodes linked by pointers. This is not suitable for direct storing on disk, since these chains of pointers can be rather long which would require too many disk accesses. In contrast, disk-based data structures should have a high fanout to minimize I/O. The challenge addressed by SP-GiST is to map search tree nodes to disk pages in such a way that a search need access only a few disk pages, even if it traverses many nodes.

Like GiST, SP-GiST is meant to allow the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert.

Some of the information here is derived from Purdue University's SP-GiST Indexing Project web site[1]. The SP-GiST implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov, and there is more information on their web site[2].

57.2. Built-in Operator Classes

The core PostgreSQL distribution includes the SP-GiST operator classes shown in Table 57-1.

Table 57-1. Built-in SP-GiST Operator Classes

Name	Indexed Data Type	Indexable Operators
kd_point_ops	point	<< <@ <^ >> >^ ~=
quad_point_ops	point	<< <@ <^ >> >^ ~=
range_ops	any range type	&& &< &> -|- << <@ = >> @>
text_ops	text	< <= = > >= ~<=~ ~<~ ~>=~ ~>~

Of the two operator classes for type point, quad_point_ops is the default. kd_point_ops supports the same operators but uses a different index data structure which may offer better performance in some applications.

1. http://www.cs.purdue.edu/spgist/
2. http://www.sai.msu.su/~megera/wiki/spgist_dev

57.3. Extensibility

SP-GiST offers an interface with a high level of abstraction, requiring the access method developer to implement only methods specific to a given data type. The SP-GiST core is responsible for efficient disk mapping and searching the tree structure. It also takes care of concurrency and logging considerations.

Leaf tuples of an SP-GiST tree contain values of the same data type as the indexed column. Leaf tuples at the root level will always contain the original indexed data value, but leaf tuples at lower levels might contain only a compressed representation, such as a suffix. In that case the operator class support functions must be able to reconstruct the original value using information accumulated from the inner tuples that are passed through to reach the leaf level.

Inner tuples are more complex, since they are branching points in the search tree. Each inner tuple contains a set of one or more *nodes*, which represent groups of similar leaf values. A node contains a downlink that leads to either another, lower-level inner tuple, or a short list of leaf tuples that all lie on the same index page. Each node has a *label* that describes it; for example, in a radix tree the node label could be the next character of the string value. Optionally, an inner tuple can have a *prefix* value that describes all its members. In a radix tree this could be the common prefix of the represented strings. The prefix value is not necessarily really a prefix, but can be any data needed by the operator class; for example, in a quad-tree it can store the central point that the four quadrants are measured with respect to. A quad-tree inner tuple would then also contain four nodes corresponding to the quadrants around this central point.

Some tree algorithms require knowledge of level (or depth) of the current tuple, so the SP-GiST core provides the possibility for operator classes to manage level counting while descending the tree. There is also support for incrementally reconstructing the represented value when that is needed.

> **Note:** The SP-GiST core code takes care of null entries. Although SP-GiST indexes do store entries for nulls in indexed columns, this is hidden from the index operator class code: no null index entries or search conditions will ever be passed to the operator class methods. (It is assumed that SP-GiST operators are strict and so cannot succeed for null values.) Null values are therefore not discussed further here.

There are five user-defined methods that an index operator class for SP-GiST must provide. All five follow the convention of accepting two `internal` arguments, the first of which is a pointer to a C struct containing input values for the support method, while the second argument is a pointer to a C struct where output values must be placed. Four of the methods just return `void`, since all their results appear in the output struct; but `leaf_consistent` additionally returns a `boolean` result. The methods must not modify any fields of their input structs. In all cases, the output struct is initialized to zeroes before calling the user-defined method.

The five user-defined methods are:

`config`

Returns static information about the index implementation, including the data type OIDs of the prefix and node label data types.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_config(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgConfigIn` C struct, containing input data for the function. The second argument is a pointer to a `spgConfigOut` C struct, which the function must fill with result data.

```
typedef struct spgConfigIn
{
    Oid         attType;        /* Data type to be indexed */
} spgConfigIn;

typedef struct spgConfigOut
{
    Oid         prefixType;     /* Data type of inner-tuple prefixes */
    Oid         labelType;      /* Data type of inner-tuple node labels */
    bool        canReturnData;  /* Opclass can reconstruct original data */
    bool        longValuesOK;   /* Opclass can cope with values > 1 page */
} spgConfigOut;
```

`attType` is passed in order to support polymorphic index operator classes; for ordinary fixed-data-type operator classes, it will always have the same value and so can be ignored.

For operator classes that do not use prefixes, `prefixType` can be set to `VOIDOID`. Likewise, for operator classes that do not use node labels, `labelType` can be set to `VOIDOID`. `canReturnData` should be set true if the operator class is capable of reconstructing the originally-supplied index value. `longValuesOK` should be set true only when the `attType` is of variable length and the operator class is capable of segmenting long values by repeated suffixing (see Section 57.4.1).

`choose`

Chooses a method for inserting a new value into an inner tuple.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_choose(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgChooseIn` C struct, containing input data for the function. The second argument is a pointer to a `spgChooseOut` C struct, which the function must fill with result data.

```
typedef struct spgChooseIn
{
    Datum       datum;          /* original datum to be indexed */
    Datum       leafDatum;      /* current datum to be stored at leaf */
    int         level;          /* current level (counting from zero) */

    /* Data from current inner tuple */
    bool        allTheSame;     /* tuple is marked all-the-same? */
    bool        hasPrefix;      /* tuple has a prefix? */
    Datum       prefixDatum;    /* if so, the prefix value */
    int         nNodes;         /* number of nodes in the inner tuple */
    Datum      *nodeLabels;     /* node label values (NULL if none) */
} spgChooseIn;

typedef enum spgChooseResultType
{
    spgMatchNode = 1,           /* descend into existing node */
    spgAddNode,                 /* add a node to the inner tuple */
    spgSplitTuple               /* split inner tuple (change its prefix) */
} spgChooseResultType;

typedef struct spgChooseOut
{
    spgChooseResultType resultType;     /* action code, see above */
    union
    {
```

```
        struct                  /* results for spgMatchNode */
        {
            int         nodeN;      /* descend to this node (index from 0) */
            int         levelAdd;   /* increment level by this much */
            Datum       restDatum;  /* new leaf datum */
        }           matchNode;
        struct                  /* results for spgAddNode */
        {
            Datum       nodeLabel;  /* new node's label */
            int         nodeN;      /* where to insert it (index from 0) */
        }           addNode;
        struct                  /* results for spgSplitTuple */
        {
            /* Info to form new inner tuple with one node */
            bool        prefixHasPrefix;    /* tuple should have a prefix? */
            Datum       prefixPrefixDatum;  /* if so, its value */
            Datum       nodeLabel;          /* node's label */

            /* Info to form new lower-level inner tuple with all old nodes */
            bool        postfixHasPrefix;   /* tuple should have a prefix? */
            Datum       postfixPrefixDatum; /* if so, its value */
        }           splitTuple;
    }           result;
} spgChooseOut;
```

`datum` is the original datum that was to be inserted into the index. `leafDatum` is initially the same as `datum`, but can change at lower levels of the tree if the `choose` or `picksplit` methods change it. When the insertion search reaches a leaf page, the current value of `leafDatum` is what will be stored in the newly created leaf tuple. `level` is the current inner tuple's level, starting at zero for the root level. `allTheSame` is true if the current inner tuple is marked as containing multiple equivalent nodes (see Section 57.4.3). `hasPrefix` is true if the current inner tuple contains a prefix; if so, `prefixDatum` is its value. `nNodes` is the number of child nodes contained in the inner tuple, and `nodeLabels` is an array of their label values, or NULL if there are no labels.

The `choose` function can determine either that the new value matches one of the existing child nodes, or that a new child node must be added, or that the new value is inconsistent with the tuple prefix and so the inner tuple must be split to create a less restrictive prefix.

If the new value matches one of the existing child nodes, set `resultType` to `spgMatchNode`. Set `nodeN` to the index (from zero) of that node in the node array. Set `levelAdd` to the increment in `level` caused by descending through that node, or leave it as zero if the operator class does not use levels. Set `restDatum` to equal `datum` if the operator class does not modify datums from one level to the next, or otherwise set it to the modified value to be used as `leafDatum` at the next level.

If a new child node must be added, set `resultType` to `spgAddNode`. Set `nodeLabel` to the label to be used for the new node, and set `nodeN` to the index (from zero) at which to insert the node in the node array. After the node has been added, the `choose` function will be called again with the modified inner tuple; that call should result in an `spgMatchNode` result.

If the new value is inconsistent with the tuple prefix, set `resultType` to `spgSplitTuple`. This action moves all the existing nodes into a new lower-level inner tuple, and replaces the existing inner tuple with a tuple having a single node that links to the new lower-level inner tuple. Set `prefixHasPrefix` to indicate whether the new upper tuple should have a prefix, and if so set `prefixPrefixDatum` to the prefix value. This new prefix value must be sufficiently less restrictive than the original to accept the new value to be indexed, and it should be no longer

than the original prefix. Set `nodeLabel` to the label to be used for the node that will point to the new lower-level inner tuple. Set `postfixHasPrefix` to indicate whether the new lower-level inner tuple should have a prefix, and if so set `postfixPrefixDatum` to the prefix value. The combination of these two prefixes and the additional label must have the same meaning as the original prefix, because there is no opportunity to alter the node labels that are moved to the new lower-level tuple, nor to change any child index entries. After the node has been split, the `choose` function will be called again with the replacement inner tuple. That call will usually result in an `spgAddNode` result, since presumably the node label added in the split step will not match the new value; so after that, there will be a third call that finally returns `spgMatchNode` and allows the insertion to descend to the leaf level.

`picksplit`

Decides how to create a new inner tuple over a set of leaf tuples.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_picksplit(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgPickSplitIn` C struct, containing input data for the function. The second argument is a pointer to a `spgPickSplitOut` C struct, which the function must fill with result data.

```
typedef struct spgPickSplitIn
{
    int          nTuples;        /* number of leaf tuples */
    Datum       *datums;         /* their datums (array of length nTuples) */
    int          level;          /* current level (counting from zero) */
} spgPickSplitIn;

typedef struct spgPickSplitOut
{
    bool         hasPrefix;      /* new inner tuple should have a prefix? */
    Datum        prefixDatum;    /* if so, its value */

    int          nNodes;         /* number of nodes for new inner tuple */
    Datum       *nodeLabels;     /* their labels (or NULL for no labels) */

    int         *mapTuplesToNodes;   /* node index for each leaf tuple */
    Datum       *leafTupleDatums;    /* datum to store in each new leaf tuple */
} spgPickSplitOut;
```

`nTuples` is the number of leaf tuples provided. `datums` is an array of their datum values. `level` is the current level that all the leaf tuples share, which will become the level of the new inner tuple.

Set `hasPrefix` to indicate whether the new inner tuple should have a prefix, and if so set `prefixDatum` to the prefix value. Set `nNodes` to indicate the number of nodes that the new inner tuple will contain, and set `nodeLabels` to an array of their label values. (If the nodes do not require labels, set `nodeLabels` to NULL; see Section 57.4.2 for details.) Set `mapTuplesToNodes` to an array that gives the index (from zero) of the node that each leaf tuple should be assigned to. Set `leafTupleDatums` to an array of the values to be stored in the new leaf tuples (these will be the same as the input `datums` if the operator class does not modify datums from one level to the next). Note that the `picksplit` function is responsible for palloc'ing the `nodeLabels`, `mapTuplesToNodes` and `leafTupleDatums` arrays.

If more than one leaf tuple is supplied, it is expected that the `picksplit` function will classify them into more than one node; otherwise it is not possible to split the leaf tuples across multiple pages, which is the ultimate purpose of this operation. Therefore, if the `picksplit` function ends up placing all the leaf tuples in the same node, the core SP-GiST code will override that

decision and generate an inner tuple in which the leaf tuples are assigned at random to several identically-labeled nodes. Such a tuple is marked `allTheSame` to signify that this has happened. The `choose` and `inner_consistent` functions must take suitable care with such inner tuples. See Section 57.4.3 for more information.

`picksplit` can be applied to a single leaf tuple only in the case that the `config` function set `longValuesOK` to true and a larger-than-a-page input value has been supplied. In this case the point of the operation is to strip off a prefix and produce a new, shorter leaf datum value. The call will be repeated until a leaf datum short enough to fit on a page has been produced. See Section 57.4.1 for more information.

`inner_consistent`

Returns set of nodes (branches) to follow during tree search.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_inner_consistent(internal, internal) RETURNS void ...
```

The first argument is a pointer to a `spgInnerConsistentIn` C struct, containing input data for the function. The second argument is a pointer to a `spgInnerConsistentOut` C struct, which the function must fill with result data.

```
typedef struct spgInnerConsistentIn
{
    ScanKey     scankeys;       /* array of operators and comparison values */
    int         nkeys;          /* length of array */

    Datum       reconstructedValue;     /* value reconstructed at parent */
    int         level;          /* current level (counting from zero) */
    bool        returnData;     /* original data must be returned? */

    /* Data from current inner tuple */
    bool        allTheSame;     /* tuple is marked all-the-same? */
    bool        hasPrefix;      /* tuple has a prefix? */
    Datum       prefixDatum;    /* if so, the prefix value */
    int         nNodes;         /* number of nodes in the inner tuple */
    Datum      *nodeLabels;     /* node label values (NULL if none) */
} spgInnerConsistentIn;

typedef struct spgInnerConsistentOut
{
    int         nNodes;         /* number of child nodes to be visited */
    int        *nodeNumbers;    /* their indexes in the node array */
    int        *levelAdds;      /* increment level by this much for each */
    Datum      *reconstructedValues;    /* associated reconstructed values */
} spgInnerConsistentOut;
```

The array `scankeys`, of length `nkeys`, describes the index search condition(s). These conditions are combined with AND — only index entries that satisfy all of them are interesting. (Note that `nkeys` = 0 implies that all index entries satisfy the query.) Usually the consistent function only cares about the `sk_strategy` and `sk_argument` fields of each array entry, which respectively give the indexable operator and comparison value. In particular it is not necessary to check `sk_flags` to see if the comparison value is NULL, because the SP-GiST core code will filter out such conditions. `reconstructedValue` is the value reconstructed for the parent tuple; it is `(Datum) 0` at the root level or if the `inner_consistent` function did not provide a value at the parent level. `level` is the current inner tuple's level, starting at zero for the root level. `returnData` is `true` if reconstructed data is required for this query; this will only be so if the `config` function asserted `canReturnData`. `allTheSame` is true if the current inner tuple is marked "all-the-same"; in this case all the nodes have the same label (if any) and so either all

or none of them match the query (see Section 57.4.3). `hasPrefix` is true if the current inner tuple contains a prefix; if so, `prefixDatum` is its value. `nNodes` is the number of child nodes contained in the inner tuple, and `nodeLabels` is an array of their label values, or NULL if the nodes do not have labels.

`nNodes` must be set to the number of child nodes that need to be visited by the search, and `nodeNumbers` must be set to an array of their indexes. If the operator class keeps track of levels, set `levelAdds` to an array of the level increments required when descending to each node to be visited. (Often these increments will be the same for all the nodes, but that's not necessarily so, so an array is used.) If value reconstruction is needed, set `reconstructedValues` to an array of the values reconstructed for each child node to be visited; otherwise, leave `reconstructedValues` as NULL. Note that the `inner_consistent` function is responsible for palloc'ing the `nodeNumbers`, `levelAdds` and `reconstructedValues` arrays.

`leaf_consistent`

Returns true if a leaf tuple satisfies a query.

The SQL declaration of the function must look like this:

```
CREATE FUNCTION my_leaf_consistent(internal, internal) RETURNS bool ...
```

The first argument is a pointer to a `spgLeafConsistentIn` C struct, containing input data for the function. The second argument is a pointer to a `spgLeafConsistentOut` C struct, which the function must fill with result data.

```
typedef struct spgLeafConsistentIn
{
    ScanKey     scankeys;       /* array of operators and comparison values */
    int         nkeys;          /* length of array */

    Datum       reconstructedValue;     /* value reconstructed at parent */
    int         level;          /* current level (counting from zero) */
    bool        returnData;     /* original data must be returned? */

    Datum       leafDatum;      /* datum in leaf tuple */
} spgLeafConsistentIn;

typedef struct spgLeafConsistentOut
{
    Datum       leafValue;      /* reconstructed original data, if any */
    bool        recheck;        /* set true if operator must be rechecked */
} spgLeafConsistentOut;
```

The array `scankeys`, of length `nkeys`, describes the index search condition(s). These conditions are combined with AND — only index entries that satisfy all of them satisfy the query. (Note that `nkeys` = 0 implies that all index entries satisfy the query.) Usually the consistent function only cares about the `sk_strategy` and `sk_argument` fields of each array entry, which respectively give the indexable operator and comparison value. In particular it is not necessary to check `sk_flags` to see if the comparison value is NULL, because the SP-GiST core code will filter out such conditions. `reconstructedValue` is the value reconstructed for the parent tuple; it is `(Datum) 0` at the root level or if the `inner_consistent` function did not provide a value at the parent level. `level` is the current leaf tuple's level, starting at zero for the root level. `returnData` is `true` if reconstructed data is required for this query; this will only be so if the `config` function asserted `canReturnData`. `leafDatum` is the key value stored in the current leaf tuple.

The function must return `true` if the leaf tuple matches the query, or `false` if not. In the `true` case, if `returnData` is `true` then `leafValue` must be set to the value originally supplied to be

indexed for this leaf tuple. Also, `recheck` may be set to `true` if the match is uncertain and so the operator(s) must be re-applied to the actual heap tuple to verify the match.

All the SP-GiST support methods are normally called in a short-lived memory context; that is, `CurrentMemoryContext` will be reset after processing of each tuple. It is therefore not very important to worry about pfree'ing everything you palloc. (The `config` method is an exception: it should try to avoid leaking memory. But usually the `config` method need do nothing but assign constants into the passed parameter struct.)

If the indexed column is of a collatable data type, the index collation will be passed to all the support methods, using the standard `PG_GET_COLLATION()` mechanism.

57.4. Implementation

This section covers implementation details and other tricks that are useful for implementers of SP-GiST operator classes to know.

57.4.1. SP-GiST Limits

Individual leaf tuples and inner tuples must fit on a single index page (8KB by default). Therefore, when indexing values of variable-length data types, long values can only be supported by methods such as radix trees, in which each level of the tree includes a prefix that is short enough to fit on a page, and the final leaf level includes a suffix also short enough to fit on a page. The operator class should set `longValuesOK` to TRUE only if it is prepared to arrange for this to happen. Otherwise, the SP-GiST core will reject any request to index a value that is too large to fit on an index page.

Likewise, it is the operator class's responsibility that inner tuples do not grow too large to fit on an index page; this limits the number of child nodes that can be used in one inner tuple, as well as the maximum size of a prefix value.

Another limitation is that when an inner tuple's node points to a set of leaf tuples, those tuples must all be in the same index page. (This is a design decision to reduce seeking and save space in the links that chain such tuples together.) If the set of leaf tuples grows too large for a page, a split is performed and an intermediate inner tuple is inserted. For this to fix the problem, the new inner tuple *must* divide the set of leaf values into more than one node group. If the operator class's `picksplit` function fails to do that, the SP-GiST core resorts to extraordinary measures described in Section 57.4.3.

57.4.2. SP-GiST Without Node Labels

Some tree algorithms use a fixed set of nodes for each inner tuple; for example, in a quad-tree there are always exactly four nodes corresponding to the four quadrants around the inner tuple's centroid point. In such a case the code typically works with the nodes by number, and there is no need for explicit node labels. To suppress node labels (and thereby save some space), the `picksplit` function can return NULL for the `nodeLabels` array. This will in turn result in `nodeLabels` being NULL during subsequent calls to `choose` and `inner_consistent`. In principle, node labels could be used for some inner tuples and omitted for others in the same index.

When working with an inner tuple having unlabeled nodes, it is an error for `choose` to return `spgAddNode`, since the set of nodes is supposed to be fixed in such cases. Also, there is no provision for generating an unlabeled node in `spgSplitTuple` actions, since it is expected that an `spgAddNode` action will be needed as well.

57.4.3. "All-the-same" Inner Tuples

The SP-GiST core can override the results of the operator class's `picksplit` function when `picksplit` fails to divide the supplied leaf values into at least two node categories. When this happens, the new inner tuple is created with multiple nodes that each have the same label (if any) that `picksplit` gave to the one node it did use, and the leaf values are divided at random among these equivalent nodes. The `allTheSame` flag is set on the inner tuple to warn the `choose` and `inner_consistent` functions that the tuple does not have the node set that they might otherwise expect.

When dealing with an `allTheSame` tuple, a `choose` result of `spgMatchNode` is interpreted to mean that the new value can be assigned to any of the equivalent nodes; the core code will ignore the supplied `nodeN` value and descend into one of the nodes at random (so as to keep the tree balanced). It is an error for `choose` to return `spgAddNode`, since that would make the nodes not all equivalent; the `spgSplitTuple` action must be used if the value to be inserted doesn't match the existing nodes.

When dealing with an `allTheSame` tuple, the `inner_consistent` function should return either all or none of the nodes as targets for continuing the index search, since they are all equivalent. This may or may not require any special-case code, depending on how much the `inner_consistent` function normally assumes about the meaning of the nodes.

57.5. Examples

The PostgreSQL source distribution includes several examples of index operator classes for SP-GiST. The core system currently provides radix trees over text columns and two types of trees over points: quad-tree and k-d tree. Look into `src/backend/access/spgist/` to see the code.

Chapter 58. GIN Indexes

58.1. Introduction

GIN stands for Generalized Inverted Index. GIN is designed for handling cases where the items to be indexed are composite values, and the queries to be handled by the index need to search for element values that appear within the composite items. For example, the items could be documents, and the queries could be searches for documents containing specific words.

We use the word *item* to refer to a composite value that is to be indexed, and the word *key* to refer to an element value. GIN always stores and searches for keys, not item values per se.

A GIN index stores a set of (key, posting list) pairs, where a *posting list* is a set of row IDs in which the key occurs. The same row ID can appear in multiple posting lists, since an item can contain more than one key. Each key value is stored only once, so a GIN index is very compact for cases where the same key appears many times.

GIN is generalized in the sense that the GIN access method code does not need to know the specific operations that it accelerates. Instead, it uses custom strategies defined for particular data types. The strategy defines how keys are extracted from indexed items and query conditions, and how to determine whether a row that contains some of the key values in a query actually satisfies the query.

One advantage of GIN is that it allows the development of custom data types with the appropriate access methods, by an expert in the domain of the data type, rather than a database expert. This is much the same advantage as using GiST.

The GIN implementation in PostgreSQL is primarily maintained by Teodor Sigaev and Oleg Bartunov. There is more information about GIN on their website[1].

58.2. Built-in Operator Classes

The core PostgreSQL distribution includes the GIN operator classes shown in Table 58-1. (Some of the optional modules described in Appendix F provide additional GIN operator classes.)

Table 58-1. Built-in GIN Operator Classes

Name	Indexed Data Type	Indexable Operators
_abstime_ops	abstime[]	&& <@ = @>
_bit_ops	bit[]	&& <@ = @>
_bool_ops	boolean[]	&& <@ = @>
_bpchar_ops	character[]	&& <@ = @>
_bytea_ops	bytea[]	&& <@ = @>
_char_ops	"char"[]	&& <@ = @>
_cidr_ops	cidr[]	&& <@ = @>
_date_ops	date[]	&& <@ = @>

1. http://www.sai.msu.su/~megera/wiki/Gin

Name	Indexed Data Type	Indexable Operators
_float4_ops	float4[]	&& <@ = @>
_float8_ops	float8[]	&& <@ = @>
_inet_ops	inet[]	&& <@ = @>
_int2_ops	smallint[]	&& <@ = @>
_int4_ops	integer[]	&& <@ = @>
_int8_ops	bigint[]	&& <@ = @>
_interval_ops	interval[]	&& <@ = @>
_macaddr_ops	macaddr[]	&& <@ = @>
_money_ops	money[]	&& <@ = @>
_name_ops	name[]	&& <@ = @>
_numeric_ops	numeric[]	&& <@ = @>
_oid_ops	oid[]	&& <@ = @>
_oidvector_ops	oidvector[]	&& <@ = @>
_reltime_ops	reltime[]	&& <@ = @>
_text_ops	text[]	&& <@ = @>
_time_ops	time[]	&& <@ = @>
_timestamp_ops	timestamp[]	&& <@ = @>
_timestamptz_ops	timestamp with time zone[]	&& <@ = @>
_timetz_ops	time with time zone[]	&& <@ = @>
_tinterval_ops	tinterval[]	&& <@ = @>
_varbit_ops	bit varying[]	&& <@ = @>
_varchar_ops	character varying[]	&& <@ = @>
jsonb_ops	jsonb	? ?& ?| @>
jsonb_path_ops	jsonb	@>
tsvector_ops	tsvector	@@ @@@

Of the two operator classes for type jsonb, jsonb_ops is the default. jsonb_path_ops supports fewer operators but offers better performance for those operators. See Section 8.14.4 for details.

58.3. Extensibility

The GIN interface has a high level of abstraction, requiring the access method implementer only to implement the semantics of the data type being accessed. The GIN layer itself takes care of concurrency, logging and searching the tree structure.

All it takes to get a GIN access method working is to implement a few user-defined methods, which define the behavior of keys in the tree and the relationships between keys, indexed items, and indexable queries. In short, GIN combines extensibility with generality, code reuse, and a clean interface.

There are three methods that an operator class for GIN must provide:

```
int compare(Datum a, Datum b)
```

Compares two keys (not indexed items!) and returns an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second. Null

keys are never passed to this function.

`Datum *extractValue(Datum itemValue, int32 *nkeys, bool **nullFlags)`

Returns a palloc'd array of keys given an item to be indexed. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the item contains no keys.

`Datum *extractQuery(Datum query, int32 *nkeys, StrategyNumber n, bool **pmatch, Pointer **extra_data, bool **nullFlags, int32 *searchMode)`

Returns a palloc'd array of keys given a value to be queried; that is, `query` is the value on the right-hand side of an indexable operator whose left-hand side is the indexed column. `n` is the strategy number of the operator within the operator class (see Section 35.14.2). Often, `extractQuery` will need to consult `n` to determine the data type of `query` and the method it should use to extract key values. The number of returned keys must be stored into `*nkeys`. If any of the keys can be null, also palloc an array of `*nkeys bool` fields, store its address at `*nullFlags`, and set these null flags as needed. `*nullFlags` can be left `NULL` (its initial value) if all keys are non-null. The return value can be `NULL` if the `query` contains no keys.

`searchMode` is an output argument that allows `extractQuery` to specify details about how the search will be done. If `*searchMode` is set to `GIN_SEARCH_MODE_DEFAULT` (which is the value it is initialized to before call), only items that match at least one of the returned keys are considered candidate matches. If `*searchMode` is set to `GIN_SEARCH_MODE_INCLUDE_EMPTY`, then in addition to items containing at least one matching key, items that contain no keys at all are considered candidate matches. (This mode is useful for implementing is-subset-of operators, for example.) If `*searchMode` is set to `GIN_SEARCH_MODE_ALL`, then all non-null items in the index are considered candidate matches, whether they match any of the returned keys or not. (This mode is much slower than the other two choices, since it requires scanning essentially the entire index, but it may be necessary to implement corner cases correctly. An operator that needs this mode in most cases is probably not a good candidate for a GIN operator class.) The symbols to use for setting this mode are defined in `access/gin.h`.

`pmatch` is an output argument for use when partial match is supported. To use it, `extractQuery` must allocate an array of `*nkeys` booleans and store its address at `*pmatch`. Each element of the array should be set to TRUE if the corresponding key requires partial match, FALSE if not. If `*pmatch` is set to `NULL` then GIN assumes partial match is not required. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not support partial match.

`extra_data` is an output argument that allows `extractQuery` to pass additional data to the `consistent` and `comparePartial` methods. To use it, `extractQuery` must allocate an array of `*nkeys` Pointers and store its address at `*extra_data`, then store whatever it wants to into the individual pointers. The variable is initialized to `NULL` before call, so this argument can simply be ignored by operator classes that do not require extra data. If `*extra_data` is set, the whole array is passed to the `consistent` method, and the appropriate element to the `comparePartial` method.

An operator class must also provide a function to check if an indexed item matches the query. It comes in two flavors, a boolean `consistent` function, and a ternary `triConsistent` function. `triConsistent` covers the functionality of both, so providing triConsistent alone is sufficient. However, if the boolean variant is significantly cheaper to calculate, it can be advantageous to provide both. If only the boolean variant is provided, some optimizations that depend on refuting index items before fetching all the keys are disabled.

```
bool consistent(bool check[], StrategyNumber n, Datum query, int32 nkeys,
Pointer extra_data[], bool *recheck, Datum queryKeys[], bool nullFlags[])
```

Returns TRUE if an indexed item satisfies the query operator with strategy number `n` (or might satisfy it, if the recheck indication is returned). This function does not have direct access to the indexed item's value, since GIN does not store items explicitly. Rather, what is available is knowledge about which key values extracted from the query appear in a given indexed item. The `check` array has length `nkeys`, which is the same as the number of keys previously returned by `extractQuery` for this `query` datum. Each element of the `check` array is TRUE if the indexed item contains the corresponding query key, i.e., if (check[i] == TRUE) the i-th key of the `extractQuery` result array is present in the indexed item. The original `query` datum is passed in case the `consistent` method needs to consult it, and so are the `queryKeys[]` and `nullFlags[]` arrays previously returned by `extractQuery`. `extra_data` is the extra-data array returned by `extractQuery`, or `NULL` if none.

When `extractQuery` returns a null key in `queryKeys[]`, the corresponding `check[]` element is TRUE if the indexed item contains a null key; that is, the semantics of `check[]` are like `IS NOT DISTINCT FROM`. The `consistent` function can examine the corresponding `nullFlags[]` element if it needs to tell the difference between a regular value match and a null match.

On success, `*recheck` should be set to TRUE if the heap tuple needs to be rechecked against the query operator, or FALSE if the index test is exact. That is, a FALSE return value guarantees that the heap tuple does not match the query; a TRUE return value with `*recheck` set to FALSE guarantees that the heap tuple does match the query; and a TRUE return value with `*recheck` set to TRUE means that the heap tuple might match the query, so it needs to be fetched and rechecked by evaluating the query operator directly against the originally indexed item.

```
GinTernaryValue triConsistent(GinTernaryValue check[], StrategyNumber n,
Datum query, int32 nkeys, Pointer extra_data[], Datum queryKeys[], bool
nullFlags[])
```

`triConsistent` is similar to `consistent`, but instead of a boolean `check[]`, there are three possible values for each key: `GIN_TRUE`, `GIN_FALSE` and `GIN_MAYBE`. `GIN_FALSE` and `GIN_TRUE` have the same meaning as regular boolean values. `GIN_MAYBE` means that the presence of that key is not known. When `GIN_MAYBE` values are present, the function should only return GIN_TRUE if the item matches whether or not the index item contains the corresponding query keys. Likewise, the function must return GIN_FALSE only if the item does not match, whether or not it contains the GIN_MAYBE keys. If the result depends on the GIN_MAYBE entries, i.e. the match cannot be confirmed or refuted based on the known query keys, the function must return GIN_MAYBE.

When there are no GIN_MAYBE values in the `check` vector, `GIN_MAYBE` return value is equivalent of setting `recheck` flag in the boolean `consistent` function.

Optionally, an operator class for GIN can supply the following method:

```
int comparePartial(Datum partial_key, Datum key, StrategyNumber n, Pointer
extra_data)
```

Compare a partial-match query key to an index key. Returns an integer whose sign indicates the result: less than zero means the index key does not match the query, but the index scan should continue; zero means that the index key does match the query; greater than zero indicates that the index scan should stop because no more matches are possible. The strategy number `n` of the operator that generated the partial match query is provided, in case its semantics are needed to determine when to end the scan. Also, `extra_data` is the corresponding element of the extra-data array made by `extractQuery`, or `NULL` if none. Null keys are never passed to this function.

To support "partial match" queries, an operator class must provide the `comparePartial` method, and its `extractQuery` method must set the `pmatch` parameter when a partial-match query is encountered. See Section 58.4.2 for details.

The actual data types of the various `Datum` values mentioned above vary depending on the operator class. The item values passed to `extractValue` are always of the operator class's input type, and all key values must be of the class's `STORAGE` type. The type of the `query` argument passed to `extractQuery`, `consistent` and `triConsistent` is whatever is specified as the right-hand input type of the class member operator identified by the strategy number. This need not be the same as the item type, so long as key values of the correct type can be extracted from it.

58.4. Implementation

Internally, a GIN index contains a B-tree index constructed over keys, where each key is an element of one or more indexed items (a member of an array, for example) and where each tuple in a leaf page contains either a pointer to a B-tree of heap pointers (a "posting tree"), or a simple list of heap pointers (a "posting list") when the list is small enough to fit into a single index tuple along with the key value.

As of PostgreSQL 9.1, null key values can be included in the index. Also, placeholder nulls are included in the index for indexed items that are null or contain no keys according to `extractValue`. This allows searches that should find empty items to do so.

Multicolumn GIN indexes are implemented by building a single B-tree over composite values (column number, key value). The key values for different columns can be of different types.

58.4.1. GIN Fast Update Technique

Updating a GIN index tends to be slow because of the intrinsic nature of inverted indexes: inserting or updating one heap row can cause many inserts into the index (one for each key extracted from the indexed item). As of PostgreSQL 8.4, GIN is capable of postponing much of this work by inserting new tuples into a temporary, unsorted list of pending entries. When the table is vacuumed, or if the pending list becomes too large (larger than work_mem), the entries are moved to the main GIN data structure using the same bulk insert techniques used during initial index creation. This greatly improves GIN index update speed, even counting the additional vacuum overhead. Moreover the overhead work can be done by a background process instead of in foreground query processing.

The main disadvantage of this approach is that searches must scan the list of pending entries in addition to searching the regular index, and so a large list of pending entries will slow searches significantly. Another disadvantage is that, while most updates are fast, an update that causes the pending list to become "too large" will incur an immediate cleanup cycle and thus be much slower than other updates. Proper use of autovacuum can minimize both of these problems.

If consistent response time is more important than update speed, use of pending entries can be disabled by turning off the `FASTUPDATE` storage parameter for a GIN index. See CREATE INDEX for details.

58.4.2. Partial Match Algorithm

GIN can support "partial match" queries, in which the query does not determine an exact match for one or more keys, but the possible matches fall within a reasonably narrow range of key values (within

the key sorting order determined by the `compare` support method). The `extractQuery` method, instead of returning a key value to be matched exactly, returns a key value that is the lower bound of the range to be searched, and sets the `pmatch` flag true. The key range is then scanned using the `comparePartial` method. `comparePartial` must return zero for a matching index key, less than zero for a non-match that is still within the range to be searched, or greater than zero if the index key is past the range that could match.

58.5. GIN Tips and Tricks

Create vs. insert

Insertion into a GIN index can be slow due to the likelihood of many keys being inserted for each item. So, for bulk insertions into a table it is advisable to drop the GIN index and recreate it after finishing bulk insertion.

As of PostgreSQL 8.4, this advice is less necessary since delayed indexing is used (see Section 58.4.1 for details). But for very large updates it may still be best to drop and recreate the index.

maintenance_work_mem

Build time for a GIN index is very sensitive to the `maintenance_work_mem` setting; it doesn't pay to skimp on work memory during index creation.

work_mem

During a series of insertions into an existing GIN index that has `FASTUPDATE` enabled, the system will clean up the pending-entry list whenever the list grows larger than `work_mem`. To avoid fluctuations in observed response time, it's desirable to have pending-list cleanup occur in the background (i.e., via autovacuum). Foreground cleanup operations can be avoided by increasing `work_mem` or making autovacuum more aggressive. However, enlarging `work_mem` means that if a foreground cleanup does occur, it will take even longer.

gin_fuzzy_search_limit

The primary goal of developing GIN indexes was to create support for highly scalable full-text search in PostgreSQL, and there are often situations when a full-text search returns a very large set of results. Moreover, this often happens when the query contains very frequent words, so that the large result set is not even useful. Since reading many tuples from the disk and sorting them could take a lot of time, this is unacceptable for production. (Note that the index search itself is very fast.)

To facilitate controlled execution of such queries, GIN has a configurable soft upper limit on the number of rows returned: the `gin_fuzzy_search_limit` configuration parameter. It is set to 0 (meaning no limit) by default. If a non-zero limit is set, then the returned set is a subset of the whole result set, chosen at random.

"Soft" means that the actual number of returned results could differ somewhat from the specified limit, depending on the query and the quality of the system's random number generator.

From experience, values in the thousands (e.g., 5000 — 20000) work well.

58.6. Limitations

GIN assumes that indexable operators are strict. This means that `extractValue` will not be called at all on a null item value (instead, a placeholder index entry is created automatically), and `extractQuery` will not be called on a null query value either (instead, the query is presumed to be unsatisfiable). Note however that null key values contained within a non-null composite item or query value are supported.

58.7. Examples

The PostgreSQL source distribution includes GIN operator classes for `tsvector` and for one-dimensional arrays of all internal types. Prefix searching in `tsvector` is implemented using the GIN partial match feature. The following `contrib` modules also contain GIN operator classes:

`btree_gin`

B-tree equivalent functionality for several data types

`hstore`

Module for storing (key, value) pairs

`intarray`

Enhanced support for `int[]`

`pg_trgm`

Text similarity using trigram matching

Chapter 59. Database Physical Storage

This chapter provides an overview of the physical storage format used by PostgreSQL databases.

59.1. Database File Layout

This section describes the storage format at the level of files and directories.

Traditionally, the configuration and data files used by a database cluster are stored together within the cluster's data directory, commonly referred to as PGDATA (after the name of the environment variable that can be used to define it). A common location for PGDATA is /var/lib/pgsql/data. Multiple clusters, managed by different server instances, can exist on the same machine.

The PGDATA directory contains several subdirectories and control files, as shown in Table 59-1. In addition to these required items, the cluster configuration files postgresql.conf, pg_hba.conf, and pg_ident.conf are traditionally stored in PGDATA, although it is possible to place them elsewhere.

Table 59-1. Contents of PGDATA

Item	Description
PG_VERSION	A file containing the major version number of PostgreSQL
base	Subdirectory containing per-database subdirectories
global	Subdirectory containing cluster-wide tables, such as pg_database
pg_clog	Subdirectory containing transaction commit status data
pg_dynshmem	Subdirectory containing files used by the dynamic shared memory subsystem
pg_logical	Subdirectory containing status data for logical decoding
pg_multixact	Subdirectory containing multitransaction status data (used for shared row locks)
pg_notify	Subdirectory containing LISTEN/NOTIFY status data
pg_replslot	Subdirectory containing replication slot data
pg_serial	Subdirectory containing information about committed serializable transactions
pg_snapshots	Subdirectory containing exported snapshots
pg_stat	Subdirectory containing permanent files for the statistics subsystem
pg_stat_tmp	Subdirectory containing temporary files for the statistics subsystem

Item	Description
pg_subtrans	Subdirectory containing subtransaction status data
pg_tblspc	Subdirectory containing symbolic links to tablespaces
pg_twophase	Subdirectory containing state files for prepared transactions
pg_xlog	Subdirectory containing WAL (Write Ahead Log) files
postgresql.auto.conf	A file used for storing configuration parameters that are set by ALTER SYSTEM
postmaster.opts	A file recording the command-line options the server was last started with
postmaster.pid	A lock file recording the current postmaster process ID (PID), cluster data directory path, postmaster start timestamp, port number, Unix-domain socket directory path (empty on Windows), first valid listen_address (IP address or *, or empty if not listening on TCP), and shared memory segment ID (this file is not present after server shutdown)

For each database in the cluster there is a subdirectory within PGDATA/base, named after the database's OID in pg_database. This subdirectory is the default location for the database's files; in particular, its system catalogs are stored there.

Each table and index is stored in a separate file. For ordinary relations, these files are named after the table or index's *filenode* number, which can be found in pg_class.relfilenode. But for temporary relations, the file name is of the form t*BBB*_*FFF*, where *BBB* is the backend ID of the backend which created the file, and *FFF* is the filenode number. In either case, in addition to the main file (a/k/a main fork), each table and index has a *free space map* (see Section 59.3), which stores information about free space available in the relation. The free space map is stored in a file named with the filenode number plus the suffix _fsm. Tables also have a *visibility map*, stored in a fork with the suffix _vm, to track which pages are known to have no dead tuples. The visibility map is described further in Section 59.4. Unlogged tables and indexes have a third fork, known as the initialization fork, which is stored in a fork with the suffix _init (see Section 59.5).

Caution

Note that while a table's filenode often matches its OID, this is *not* necessarily the case; some operations, like TRUNCATE, REINDEX, CLUSTER and some forms of ALTER TABLE, can change the filenode while preserving the OID. Avoid assuming that filenode and table OID are the same. Also, for certain system catalogs including pg_class itself, pg_class.relfilenode contains zero. The actual filenode number of these catalogs is stored in a lower-level data structure, and can be obtained using the pg_relation_filenode() function.

When a table or index exceeds 1 GB, it is divided into gigabyte-sized *segments*. The first segment's file name is the same as the filenode; subsequent segments are named filenode.1, filenode.2, etc. This arrangement avoids problems on platforms that have file size limitations. (Actually, 1 GB is just the default segment size. The segment size can be adjusted using the configuration option

--with-segsize when building PostgreSQL.) In principle, free space map and visibility map forks could require multiple segments as well, though this is unlikely to happen in practice.

A table that has columns with potentially large entries will have an associated *TOAST* table, which is used for out-of-line storage of field values that are too large to keep in the table rows proper. pg_class.reltoastrelid links from a table to its TOAST table, if any. See Section 59.2 for more information.

The contents of tables and indexes are discussed further in Section 59.6.

Tablespaces make the scenario more complicated. Each user-defined tablespace has a symbolic link inside the PGDATA/pg_tblspc directory, which points to the physical tablespace directory (i.e., the location specified in the tablespace's CREATE TABLESPACE command). This symbolic link is named after the tablespace's OID. Inside the physical tablespace directory there is a subdirectory with a name that depends on the PostgreSQL server version, such as PG_9.0_201008051. (The reason for using this subdirectory is so that successive versions of the database can use the same CREATE TABLESPACE location value without conflicts.) Within the version-specific subdirectory, there is a subdirectory for each database that has elements in the tablespace, named after the database's OID. Tables and indexes are stored within that directory, using the filenode naming scheme. The pg_default tablespace is not accessed through pg_tblspc, but corresponds to PGDATA/base. Similarly, the pg_global tablespace is not accessed through pg_tblspc, but corresponds to PGDATA/global.

The pg_relation_filepath() function shows the entire path (relative to PGDATA) of any relation. It is often useful as a substitute for remembering many of the above rules. But keep in mind that this function just gives the name of the first segment of the main fork of the relation — you may need to append a segment number and/or _fsm, _vm, or _init to find all the files associated with the relation.

Temporary files (for operations such as sorting more data than can fit in memory) are created within PGDATA/base/pgsql_tmp, or within a pgsql_tmp subdirectory of a tablespace directory if a tablespace other than pg_default is specified for them. The name of a temporary file has the form pgsql_tmp*PPP*.*NNN*, where *PPP* is the PID of the owning backend and *NNN* distinguishes different temporary files of that backend.

59.2. TOAST

This section provides an overview of TOAST (The Oversized-Attribute Storage Technique).

PostgreSQL uses a fixed page size (commonly 8 kB), and does not allow tuples to span multiple pages. Therefore, it is not possible to store very large field values directly. To overcome this limitation, large field values are compressed and/or broken up into multiple physical rows. This happens transparently to the user, with only small impact on most of the backend code. The technique is affectionately known as TOAST (or "the best thing since sliced bread").

Only certain data types support TOAST — there is no need to impose the overhead on data types that cannot produce large field values. To support TOAST, a data type must have a variable-length (*varlena*) representation, in which the first 32-bit word of any stored value contains the total length of the value in bytes (including itself). TOAST does not constrain the rest of the representation. All the C-level functions supporting a TOAST-able data type must be careful to handle TOASTed input values. (This is normally done by invoking PG_DETOAST_DATUM before doing anything with an input value, but in some cases more efficient approaches are possible.)

TOAST usurps two bits of the varlena length word (the high-order bits on big-endian machines, the low-order bits on little-endian machines), thereby limiting the logical size of any value of a TOAST-able data type to 1 GB (2^{30} - 1 bytes). When both bits are zero, the value is an ordinary un-TOASTed value of the data type, and the remaining bits of the length word give the total datum size (including

length word) in bytes. When the highest-order or lowest-order bit is set, the value has only a single-byte header instead of the normal four-byte header, and the remaining bits give the total datum size (including length byte) in bytes. As a special case, if the remaining bits are all zero (which would be impossible for a self-inclusive length), the value is a pointer to out-of-line data stored in a separate TOAST table. (The size of a TOAST pointer is given in the second byte of the datum.) Values with single-byte headers aren't aligned on any particular boundary, either. Lastly, when the highest-order or lowest-order bit is clear but the adjacent bit is set, the content of the datum has been compressed and must be decompressed before use. In this case the remaining bits of the length word give the total size of the compressed datum, not the original data. Note that compression is also possible for out-of-line data but the varlena header does not tell whether it has occurred — the content of the TOAST pointer tells that, instead.

If any of the columns of a table are TOAST-able, the table will have an associated TOAST table, whose OID is stored in the table's `pg_class.reltoastrelid` entry. Out-of-line TOASTed values are kept in the TOAST table, as described in more detail below.

The compression technique used is a fairly simple and very fast member of the LZ family of compression techniques. See `src/backend/utils/adt/pg_lzcompress.c` for the details.

Out-of-line values are divided (after compression if used) into chunks of at most `TOAST_MAX_CHUNK_SIZE` bytes (by default this value is chosen so that four chunk rows will fit on a page, making it about 2000 bytes). Each chunk is stored as a separate row in the TOAST table for the owning table. Every TOAST table has the columns `chunk_id` (an OID identifying the particular TOASTed value), `chunk_seq` (a sequence number for the chunk within its value), and `chunk_data` (the actual data of the chunk). A unique index on `chunk_id` and `chunk_seq` provides fast retrieval of the values. A pointer datum representing an out-of-line TOASTed value therefore needs to store the OID of the TOAST table in which to look and the OID of the specific value (its `chunk_id`). For convenience, pointer datums also store the logical datum size (original uncompressed data length) and actual stored size (different if compression was applied). Allowing for the varlena header bytes, the total size of a TOAST pointer datum is therefore 18 bytes regardless of the actual size of the represented value.

The TOAST code is triggered only when a row value to be stored in a table is wider than `TOAST_TUPLE_THRESHOLD` bytes (normally 2 kB). The TOAST code will compress and/or move field values out-of-line until the row value is shorter than `TOAST_TUPLE_TARGET` bytes (also normally 2 kB) or no more gains can be had. During an UPDATE operation, values of unchanged fields are normally preserved as-is; so an UPDATE of a row with out-of-line values incurs no TOAST costs if none of the out-of-line values change.

The TOAST code recognizes four different strategies for storing TOAST-able columns:

- `PLAIN` prevents either compression or out-of-line storage; furthermore it disables use of single-byte headers for varlena types. This is the only possible strategy for columns of non-TOAST-able data types.
- `EXTENDED` allows both compression and out-of-line storage. This is the default for most TOAST-able data types. Compression will be attempted first, then out-of-line storage if the row is still too big.
- `EXTERNAL` allows out-of-line storage but not compression. Use of `EXTERNAL` will make substring operations on wide `text` and `bytea` columns faster (at the penalty of increased storage space) because these operations are optimized to fetch only the required parts of the out-of-line value when it is not compressed.
- `MAIN` allows compression but not out-of-line storage. (Actually, out-of-line storage will still be performed for such columns, but only as a last resort when there is no other way to make the row

small enough to fit on a page.)

Each TOAST-able data type specifies a default strategy for columns of that data type, but the strategy for a given table column can be altered with `ALTER TABLE SET STORAGE`.

This scheme has a number of advantages compared to a more straightforward approach such as allowing row values to span pages. Assuming that queries are usually qualified by comparisons against relatively small key values, most of the work of the executor will be done using the main row entry. The big values of TOASTed attributes will only be pulled out (if selected at all) at the time the result set is sent to the client. Thus, the main table is much smaller and more of its rows fit in the shared buffer cache than would be the case without any out-of-line storage. Sort sets shrink also, and sorts will more often be done entirely in memory. A little test showed that a table containing typical HTML pages and their URLs was stored in about half of the raw data size including the TOAST table, and that the main table contained only about 10% of the entire data (the URLs and some small HTML pages). There was no run time difference compared to an un-TOASTed comparison table, in which all the HTML pages were cut down to 7 kB to fit.

59.3. Free Space Map

Each heap and index relation, except for hash indexes, has a Free Space Map (FSM) to keep track of available space in the relation. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_fsm` suffix. For example, if the filenode of a relation is 12345, the FSM is stored in a file called `12345_fsm`, in the same directory as the main relation file.

The Free Space Map is organized as a tree of FSM pages. The bottom level FSM pages store the free space available on each heap (or index) page, using one byte to represent each such page. The upper levels aggregate information from the lower levels.

Within each FSM page is a binary tree, stored in an array with one byte per node. Each leaf node represents a heap page, or a lower level FSM page. In each non-leaf node, the higher of its children's values is stored. The maximum value in the leaf nodes is therefore stored at the root.

See `src/backend/storage/freespace/README` for more details on how the FSM is structured, and how it's updated and searched. The pg_freespacemap module can be used to examine the information stored in free space maps.

59.4. Visibility Map

Each heap relation has a Visibility Map (VM) to keep track of which pages contain only tuples that are known to be visible to all active transactions. It's stored alongside the main relation data in a separate relation fork, named after the filenode number of the relation, plus a `_vm` suffix. For example, if the filenode of a relation is 12345, the VM is stored in a file called `12345_vm`, in the same directory as the main relation file. Note that indexes do not have VMs.

The visibility map simply stores one bit per heap page. A set bit means that all tuples on the page are known to be visible to all transactions. This means that the page does not contain any tuples that need to be vacuumed. This information can also be used by *index-only scans* to answer queries using only the index tuple.

The map is conservative in the sense that we make sure that whenever a bit is set, we know the condition is true, but if a bit is not set, it might or might not be true. Visibility map bits are only set by vacuum, but are cleared by any data-modifying operations on a page.

59.5. The Initialization Fork

Each unlogged table, and each index on an unlogged table, has an initialization fork. The initialization fork is an empty table or index of the appropriate type. When an unlogged table must be reset to empty due to a crash, the initialization fork is copied over the main fork, and any other forks are erased (they will be recreated automatically as needed).

59.6. Database Page Layout

This section provides an overview of the page format used within PostgreSQL tables and indexes.[1] Sequences and TOAST tables are formatted just like a regular table.

In the following explanation, a *byte* is assumed to contain 8 bits. In addition, the term *item* refers to an individual data value that is stored on a page. In a table, an item is a row; in an index, an item is an index entry.

Every table and index is stored as an array of *pages* of a fixed size (usually 8 kB, although a different page size can be selected when compiling the server). In a table, all the pages are logically equivalent, so a particular item (row) can be stored in any page. In indexes, the first page is generally reserved as a *metapage* holding control information, and there can be different types of pages within the index, depending on the index access method.

Table 59-2 shows the overall layout of a page. There are five parts to each page.

Table 59-2. Overall Page Layout

Item	Description
PageHeaderData	24 bytes long. Contains general information about the page, including free space pointers.
ItemIdData	Array of (offset,length) pairs pointing to the actual items. 4 bytes per item.
Free space	The unallocated space. New item pointers are allocated from the start of this area, new items from the end.
Items	The actual items themselves.
Special space	Index access method specific data. Different methods store different data. Empty in ordinary tables.

The first 24 bytes of each page consists of a page header (PageHeaderData). Its format is detailed in Table 59-3. The first two fields track the most recent WAL entry related to this page. Next is a 2-byte field containing flag bits. This is followed by three 2-byte integer fields (`pd_lower`, `pd_upper`, and `pd_special`). These contain byte offsets from the page start to the start of unallocated space, to the end of unallocated space, and to the start of the special space. The next 2 bytes of the page header, `pd_pagesize_version`, store both the page size and a version indicator. Beginning with PostgreSQL 8.3 the version number is 4; PostgreSQL 8.1 and 8.2 used version number 3; PostgreSQL 8.0 used version number 2; PostgreSQL 7.3 and 7.4 used version number 1; prior releases used version number 0. (The basic page layout and header format has not changed in most of these versions, but the layout of heap row headers has.) The page size is basically only present as a cross-check; there

1. Actually, index access methods need not use this page format. All the existing index methods do use this basic format, but the data kept on index metapages usually doesn't follow the item layout rules.

is no support for having more than one page size in an installation. The last field is a hint that shows whether pruning the page is likely to be profitable: it tracks the oldest un-pruned XMAX on the page.

Table 59-3. PageHeaderData Layout

Field	Type	Length	Description
pd_lsn	XLogRecPtr	8 bytes	LSN: next byte after last byte of xlog record for last change to this page
pd_checksum	uint16	2 bytes	Page checksum
pd_flags	uint16	2 bytes	Flag bits
pd_lower	LocationIndex	2 bytes	Offset to start of free space
pd_upper	LocationIndex	2 bytes	Offset to end of free space
pd_special	LocationIndex	2 bytes	Offset to start of special space
pd_pagesize_version	uint16	2 bytes	Page size and layout version number information
pd_prune_xid	TransactionId	4 bytes	Oldest unpruned XMAX on page, or zero if none

All the details can be found in `src/include/storage/bufpage.h`.

Following the page header are item identifiers (`ItemIdData`), each requiring four bytes. An item identifier contains a byte-offset to the start of an item, its length in bytes, and a few attribute bits which affect its interpretation. New item identifiers are allocated as needed from the beginning of the unallocated space. The number of item identifiers present can be determined by looking at `pd_lower`, which is increased to allocate a new identifier. Because an item identifier is never moved until it is freed, its index can be used on a long-term basis to reference an item, even when the item itself is moved around on the page to compact free space. In fact, every pointer to an item (`ItemPointer`, also known as `CTID`) created by PostgreSQL consists of a page number and the index of an item identifier.

The items themselves are stored in space allocated backwards from the end of unallocated space. The exact structure varies depending on what the table is to contain. Tables and sequences both use a structure named `HeapTupleHeaderData`, described below.

The final section is the "special section" which can contain anything the access method wishes to store. For example, b-tree indexes store links to the page's left and right siblings, as well as some other data relevant to the index structure. Ordinary tables do not use a special section at all (indicated by setting `pd_special` to equal the page size).

All table rows are structured in the same way. There is a fixed-size header (occupying 23 bytes on most machines), followed by an optional null bitmap, an optional object ID field, and the user data. The header is detailed in Table 59-4. The actual user data (columns of the row) begins at the offset indicated by `t_hoff`, which must always be a multiple of the MAXALIGN distance for the platform. The null bitmap is only present if the *HEAP_HASNULL* bit is set in `t_infomask`. If it is present it begins just after the fixed header and occupies enough bytes to have one bit per data column (that is, `t_natts` bits altogether). In this list of bits, a 1 bit indicates not-null, a 0 bit is a null. When the bitmap

is not present, all columns are assumed not-null. The object ID is only present if the *HEAP_HASOID* bit is set in `t_infomask`. If present, it appears just before the `t_hoff` boundary. Any padding needed to make `t_hoff` a MAXALIGN multiple will appear between the null bitmap and the object ID. (This in turn ensures that the object ID is suitably aligned.)

Table 59-4. HeapTupleHeaderData Layout

Field	Type	Length	Description
t_xmin	TransactionId	4 bytes	insert XID stamp
t_xmax	TransactionId	4 bytes	delete XID stamp
t_cid	CommandId	4 bytes	insert and/or delete CID stamp (overlays with t_xvac)
t_xvac	TransactionId	4 bytes	XID for VACUUM operation moving a row version
t_ctid	ItemPointerData	6 bytes	current TID of this or newer row version
t_infomask2	uint16	2 bytes	number of attributes, plus various flag bits
t_infomask	uint16	2 bytes	various flag bits
t_hoff	uint8	1 byte	offset to user data

All the details can be found in `src/include/access/htup.h`.

Interpreting the actual data can only be done with information obtained from other tables, mostly `pg_attribute`. The key values needed to identify field locations are `attlen` and `attalign`. There is no way to directly get a particular attribute, except when there are only fixed width fields and no null values. All this trickery is wrapped up in the functions *heap_getattr*, *fastgetattr* and *heap_getsysattr*.

To read the data you need to examine each attribute in turn. First check whether the field is NULL according to the null bitmap. If it is, go to the next. Then make sure you have the right alignment. If the field is a fixed width field, then all the bytes are simply placed. If it's a variable length field (attlen = -1) then it's a bit more complicated. All variable-length data types share the common header structure `struct varlena`, which includes the total length of the stored value and some flag bits. Depending on the flags, the data can be either inline or in a TOAST table; it might be compressed, too (see Section 59.2).

Chapter 60. BKI Backend Interface

Backend Interface (BKI) files are scripts in a special language that is understood by the PostgreSQL backend when running in the "bootstrap" mode. The bootstrap mode allows system catalogs to be created and filled from scratch, whereas ordinary SQL commands require the catalogs to exist already. BKI files can therefore be used to create the database system in the first place. (And they are probably not useful for anything else.)

initdb uses a BKI file to do part of its job when creating a new database cluster. The input file used by initdb is created as part of building and installing PostgreSQL by a program named `genbki.pl`, which reads some specially formatted C header files in the `src/include/catalog/` directory of the source tree. The created BKI file is called `postgres.bki` and is normally installed in the `share` subdirectory of the installation tree.

Related information can be found in the documentation for initdb.

60.1. BKI File Format

This section describes how the PostgreSQL backend interprets BKI files. This description will be easier to understand if the `postgres.bki` file is at hand as an example.

BKI input consists of a sequence of commands. Commands are made up of a number of tokens, depending on the syntax of the command. Tokens are usually separated by whitespace, but need not be if there is no ambiguity. There is no special command separator; the next token that syntactically cannot belong to the preceding command starts a new one. (Usually you would put a new command on a new line, for clarity.) Tokens can be certain key words, special characters (parentheses, commas, etc.), numbers, or double-quoted strings. Everything is case sensitive.

Lines starting with `#` are ignored.

60.2. BKI Commands

`create` *`tablename`* *`tableoid`* [`bootstrap`] [`shared_relation`] [`without_oids`] [`rowtype_oid` *`oid`*] (*`name1`* = *`type1`* [, *`name2`* = *`type2`*, ...])

Create a table named *`tablename`*, and having the OID *`tableoid`*, with the columns given in parentheses.

The following column types are supported directly by `bootstrap.c`: `bool`, `bytea`, `char` (1 byte), `name`, `int2`, `int4`, `regproc`, `regclass`, `regtype`, `text`, `oid`, `tid`, `xid`, `cid`, `int2vector`, `oidvector`, `_int4` (array), `_text` (array), `_oid` (array), `_char` (array), `_aclitem` (array). Although it is possible to create tables containing columns of other types, this cannot be done until after `pg_type` has been created and filled with appropriate entries. (That effectively means that only these column types can be used in bootstrapped tables, but non-bootstrap catalogs can contain any built-in type.)

When `bootstrap` is specified, the table will only be created on disk; nothing is entered into `pg_class`, `pg_attribute`, etc, for it. Thus the table will not be accessible by ordinary SQL

operations until such entries are made the hard way (with `insert` commands). This option is used for creating `pg_class` etc themselves.

The table is created as shared if `shared_relation` is specified. It will have OIDs unless `without_oids` is specified. The table's row type OID (`pg_type` OID) can optionally be specified via the `rowtype_oid` clause; if not specified, an OID is automatically generated for it. (The `rowtype_oid` clause is useless if `bootstrap` is specified, but it can be provided anyway for documentation.)

`open` *`tablename`*

Open the table named *`tablename`* for insertion of data. Any currently open table is closed.

`close` [*`tablename`*]

Close the open table. The name of the table can be given as a cross-check, but this is not required.

`insert` [`OID =` *`oid_value`*] `(` *`value1 value2`* ... `)`

Insert a new row into the open table using *`value1`*, *`value2`*, etc., for its column values and *`oid_value`* for its OID. If *`oid_value`* is zero (0) or the clause is omitted, and the table has OIDs, then the next available OID is assigned.

NULL values can be specified using the special key word `_null_`. Values containing spaces must be double quoted.

`declare` [`unique`] `index` *`indexname indexoid`* `on` *`tablename`* `using` *`amname`* `(` *`opclass1 name1`* [, ...] `)`

Create an index named *`indexname`*, having OID *`indexoid`*, on the table named *`tablename`*, using the *`amname`* access method. The fields to index are called *`name1`*, *`name2`* etc., and the operator classes to use are *`opclass1`*, *`opclass2`* etc., respectively. The index file is created and appropriate catalog entries are made for it, but the index contents are not initialized by this command.

`declare toast` *`toasttableoid toastindexoid`* `on` *`tablename`*

Create a TOAST table for the table named *`tablename`*. The TOAST table is assigned OID *`toasttableoid`* and its index is assigned OID *`toastindexoid`*. As with `declare index`, filling of the index is postponed.

`build indices`

Fill in the indices that have previously been declared.

60.3. Structure of the Bootstrap BKI File

The `open` command cannot be used until the tables it uses exist and have entries for the table that is to be opened. (These minimum tables are `pg_class`, `pg_attribute`, `pg_proc`, and `pg_type`.) To allow those tables themselves to be filled, `create` with the `bootstrap` option implicitly opens the created table for data insertion.

Also, the `declare index` and `declare toast` commands cannot be used until the system catalogs they need have been created and filled in.

Thus, the structure of the `postgres.bki` file has to be:

1. `create bootstrap` one of the critical tables
2. `insert` data describing at least the critical tables

3. `close`
4. Repeat for the other critical tables.
5. `create` (without `bootstrap`) a noncritical table
6. `open`
7. `insert` desired data
8. `close`
9. Repeat for the other noncritical tables.
10. Define indexes and toast tables.
11. `build indices`

There are doubtless other, undocumented ordering dependencies.

60.4. Example

The following sequence of commands will create the table `test_table` with OID 420, having two columns `cola` and `colb` of type `int4` and `text`, respectively, and insert two rows into the table:

```
create test_table 420 (cola = int4, colb = text)
open test_table
insert OID=421 ( 1 "value1" )
insert OID=422 ( 2 _null_ )
close test_table
```

Chapter 61. How the Planner Uses Statistics

This chapter builds on the material covered in Section 14.1 and Section 14.2 to show some additional details about how the planner uses the system statistics to estimate the number of rows each part of a query might return. This is a significant part of the planning process, providing much of the raw material for cost calculation.

The intent of this chapter is not to document the code in detail, but to present an overview of how it works. This will perhaps ease the learning curve for someone who subsequently wishes to read the code.

61.1. Row Estimation Examples

The examples shown below use tables in the PostgreSQL regression test database. The outputs shown are taken from version 8.3. The behavior of earlier (or later) versions might vary. Note also that since `ANALYZE` uses random sampling while producing statistics, the results will change slightly after any new `ANALYZE`.

Let's start with a very simple query:

```
EXPLAIN SELECT * FROM tenk1;

                         QUERY PLAN
-------------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..458.00 rows=10000 width=244)
```

How the planner determines the cardinality of `tenk1` is covered in Section 14.2, but is repeated here for completeness. The number of pages and rows is looked up in `pg_class`:

```
SELECT relpages, reltuples FROM pg_class WHERE relname = 'tenk1';

 relpages | reltuples
----------+-----------
      358 |     10000
```

These numbers are current as of the last `VACUUM` or `ANALYZE` on the table. The planner then fetches the actual current number of pages in the table (this is a cheap operation, not requiring a table scan). If that is different from `relpages` then `reltuples` is scaled accordingly to arrive at a current number-of-rows estimate. In this case the value of `relpages` is up-to-date so the rows estimate is the same as `reltuples`.

Let's move on to an example with a range condition in its `WHERE` clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000;

                                  QUERY PLAN
------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=24.06..394.64 rows=1007 width=244)
   Recheck Cond: (unique1 < 1000)
   ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..23.80 rows=1007 width=0)
         Index Cond: (unique1 < 1000)
```

The planner examines the `WHERE` clause condition and looks up the selectivity function for the operator `<` in `pg_operator`. This is held in the column `oprrest`, and the entry in this case is `scalarltsel`. The `scalarltsel` function retrieves the histogram for `unique1` from `pg_statistics`. For manual queries it is more convenient to look in the simpler `pg_stats` view:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='unique1';

                    histogram_bounds
------------------------------------------------------
 {0,993,1997,3050,4040,5036,5957,7057,8029,9016,9995}
```

Next the fraction of the histogram occupied by "< 1000" is worked out. This is the selectivity. The histogram divides the range into equal frequency buckets, so all we have to do is locate the bucket that our value is in and count *part* of it and *all* of the ones before. The value 1000 is clearly in the second bucket (993-1997). Assuming a linear distribution of values inside each bucket, we can calculate the selectivity as:

```
selectivity = (1 + (1000 - bucket[2].min)/(bucket[2].max - bucket[2].min))/num_buckets
            = (1 + (1000 - 993)/(1997 - 993))/10
            = 0.100697
```

that is, one whole bucket plus a linear fraction of the second, divided by the number of buckets. The estimated number of rows can now be calculated as the product of the selectivity and the cardinality of `tenk1`:

```
rows = rel_cardinality * selectivity
     = 10000 * 0.100697
     = 1007  (rounding off)
```

Next let's consider an example with an equality condition in its `WHERE` clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringu1 = 'CRAAAA';

                        QUERY PLAN
----------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..483.00 rows=30 width=244)
   Filter: (stringu1 = 'CRAAAA'::name)
```

Again the planner examines the `WHERE` clause condition and looks up the selectivity function for `=`, which is `eqsel`. For equality estimation the histogram is not useful; instead the list of *most common values* (MCVs) is used to determine the selectivity. Let's have a look at the MCVs, with some additional columns that will be useful later:

```
SELECT null_frac, n_distinct, most_common_vals, most_common_freqs FROM pg_stats
WHERE tablename='tenk1' AND attname='stringu1';

null_frac         | 0
n_distinct        | 676
most_common_vals  | {EJAAAA,BBAAAA,CRAAAA,FCAAAA,FEAAAA,GSAAAA,JOAAAA,MCAAAA,NAAAAA,WGAA
most_common_freqs | {0.00333333,0.003,0.003,0.003,0.003,0.003,0.003,0.003,0.003,0.003}
```

Since `CRAAAA` appears in the list of MCVs, the selectivity is merely the corresponding entry in the list of most common frequencies (MCFs):

```
selectivity = mcf[3]
            = 0.003
```

As before, the estimated number of rows is just the product of this with the cardinality of `tenk1`:

```
rows = 10000 * 0.003
     = 30
```

Now consider the same query, but with a constant that is not in the MCV list:

```
EXPLAIN SELECT * FROM tenk1 WHERE stringu1 = 'xxx';

                        QUERY PLAN
-----------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..483.00 rows=15 width=244)
   Filter: (stringu1 = 'xxx'::name)
```

This is quite a different problem: how to estimate the selectivity when the value is *not* in the MCV list. The approach is to use the fact that the value is not in the list, combined with the knowledge of the frequencies for all of the MCVs:

```
selectivity = (1 - sum(mvf))/(num_distinct - num_mcv)
            = (1 - (0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003 +
                    0.003 + 0.003 + 0.003 + 0.003))/(676 - 10)
            = 0.0014559
```

That is, add up all the frequencies for the MCVs and subtract them from one, then divide by the number of *other* distinct values. This amounts to assuming that the fraction of the column that is not any of the MCVs is evenly distributed among all the other distinct values. Notice that there are no null values so we don't have to worry about those (otherwise we'd subtract the null fraction from the numerator as well). The estimated number of rows is then calculated as usual:

```
rows = 10000 * 0.0014559
     = 15  (rounding off)
```

The previous example with `unique1 < 1000` was an oversimplification of what `scalarltsel` really does; now that we have seen an example of the use of MCVs, we can fill in some more detail. The example was correct as far as it went, because since `unique1` is a unique column it has no MCVs (obviously, no value is any more common than any other value). For a non-unique column, there will normally be both a histogram and an MCV list, and *the histogram does not include the portion of the column population represented by the MCVs*. We do things this way because it allows more precise estimation. In this situation `scalarltsel` directly applies the condition (e.g., "< 1000") to each value of the MCV list, and adds up the frequencies of the MCVs for which the condition is true. This gives an exact estimate of the selectivity within the portion of the table that is MCVs. The histogram is then used in the same way as above to estimate the selectivity in the portion of the table that is not MCVs, and then the two numbers are combined to estimate the overall selectivity. For example, consider

```
EXPLAIN SELECT * FROM tenk1 WHERE stringu1 < 'IAAAAA';

                        QUERY PLAN
-----------------------------------------------------------
 Seq Scan on tenk1  (cost=0.00..483.00 rows=3077 width=244)
```

```
   Filter: (stringu1 < 'IAAAAA'::name)
```

We already saw the MCV information for `stringu1`, and here is its histogram:

```
SELECT histogram_bounds FROM pg_stats
WHERE tablename='tenk1' AND attname='stringu1';

                                histogram_bounds
------------------------------------------------------------------------------
 {AAAAAA,CQAAAA,FRAAAA,IBAAAA,KRAAAA,NFAAAA,PSAAAA,SGAAAA,VAAAAA,XLAAAA,ZZAAAA}
```

Checking the MCV list, we find that the condition `stringu1 < 'IAAAAA'` is satisfied by the first six entries and not the last four, so the selectivity within the MCV part of the population is

```
selectivity = sum(relevant mvfs)
            = 0.00333333 + 0.003 + 0.003 + 0.003 + 0.003 + 0.003
            = 0.01833333
```

Summing all the MCFs also tells us that the total fraction of the population represented by MCVs is 0.03033333, and therefore the fraction represented by the histogram is 0.96966667 (again, there are no nulls, else we'd have to exclude them here). We can see that the value `IAAAAA` falls nearly at the end of the third histogram bucket. Using some rather cheesy assumptions about the frequency of different characters, the planner arrives at the estimate 0.298387 for the portion of the histogram population that is less than `IAAAAA`. We then combine the estimates for the MCV and non-MCV populations:

```
selectivity = mcv_selectivity + histogram_selectivity * histogram_fraction
            = 0.01833333 + 0.298387 * 0.96966667
            = 0.307669

rows        = 10000 * 0.307669
            = 3077  (rounding off)
```

In this particular example, the correction from the MCV list is fairly small, because the column distribution is actually quite flat (the statistics showing these particular values as being more common than others are mostly due to sampling error). In a more typical case where some values are significantly more common than others, this complicated process gives a useful improvement in accuracy because the selectivity for the most common values is found exactly.

Now let's consider a case with more than one condition in the `WHERE` clause:

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 1000 AND stringu1 = 'xxx';

                                     QUERY PLAN
------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=23.80..396.91 rows=1 width=244)
   Recheck Cond: (unique1 < 1000)
   Filter: (stringu1 = 'xxx'::name)
   ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..23.80 rows=1007 width=0)
         Index Cond: (unique1 < 1000)
```

The planner assumes that the two conditions are independent, so that the individual selectivities of the clauses can be multiplied together:

```
selectivity = selectivity(unique1 < 1000) * selectivity(stringu1 = 'xxx')
            = 0.100697 * 0.0014559
            = 0.0001466
```

```
rows        = 10000 * 0.0001466
            = 1  (rounding off)
```

Notice that the number of rows estimated to be returned from the bitmap index scan reflects only the condition used with the index; this is important since it affects the cost estimate for the subsequent heap fetches.

Finally we will examine a query that involves a join:

```
EXPLAIN SELECT * FROM tenk1 t1, tenk2 t2
WHERE t1.unique1 < 50 AND t1.unique2 = t2.unique2;

                                      QUERY PLAN
------------------------------------------------------------------------------------
 Nested Loop  (cost=4.64..456.23 rows=50 width=488)
   ->  Bitmap Heap Scan on tenk1 t1  (cost=4.64..142.17 rows=50 width=244)
         Recheck Cond: (unique1 < 50)
         ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..4.63 rows=50 width=0)
               Index Cond: (unique1 < 50)
   ->  Index Scan using tenk2_unique2 on tenk2 t2  (cost=0.00..6.27 rows=1 width=244)
         Index Cond: (unique2 = t1.unique2)
```

The restriction on `tenk1`, `unique1 < 50`, is evaluated before the nested-loop join. This is handled analogously to the previous range example. This time the value 50 falls into the first bucket of the `unique1` histogram:

```
selectivity = (0 + (50 - bucket[1].min)/(bucket[1].max - bucket[1].min))/num_buckets
            = (0 + (50 - 0)/(993 - 0))/10
            = 0.005035

rows        = 10000 * 0.005035
            = 50  (rounding off)
```

The restriction for the join is `t2.unique2 = t1.unique2`. The operator is just our familiar `=`, however the selectivity function is obtained from the `oprjoin` column of `pg_operator`, and is `eqjoinsel`. `eqjoinsel` looks up the statistical information for both `tenk2` and `tenk1`:

```
SELECT tablename, null_frac,n_distinct, most_common_vals FROM pg_stats
WHERE tablename IN ('tenk1', 'tenk2') AND attname='unique2';

tablename  | null_frac | n_distinct | most_common_vals
-----------+-----------+------------+------------------
 tenk1     |         0 |         -1 |
 tenk2     |         0 |         -1 |
```

In this case there is no MCV information for `unique2` because all the values appear to be unique, so we use an algorithm that relies only on the number of distinct values for both relations together with their null fractions:

```
selectivity = (1 - null_frac1) * (1 - null_frac2) * min(1/num_distinct1, 1/num_distinct2
            = (1 - 0) * (1 - 0) / max(10000, 10000)
            = 0.0001
```

This is, subtract the null fraction from one for each of the relations, and divide by the maximum of the numbers of distinct values. The number of rows that the join is likely to emit is calculated as the cardinality of the Cartesian product of the two inputs, multiplied by the selectivity:

```
rows = (outer_cardinality * inner_cardinality) * selectivity
     = (50 * 10000) * 0.0001
     = 50
```

Had there been MCV lists for the two columns, `eqjoinsel` would have used direct comparison of the MCV lists to determine the join selectivity within the part of the column populations represented by the MCVs. The estimate for the remainder of the populations follows the same approach shown here.

Notice that we showed `inner_cardinality` as 10000, that is, the unmodified size of `tenk2`. It might appear from inspection of the `EXPLAIN` output that the estimate of join rows comes from 50 * 1, that is, the number of outer rows times the estimated number of rows obtained by each inner index scan on `tenk2`. But this is not the case: the join relation size is estimated before any particular join plan has been considered. If everything is working well then the two ways of estimating the join size will produce about the same answer, but due to round-off error and other factors they sometimes diverge significantly.

For those interested in further details, estimation of the size of a table (before any `WHERE` clauses) is done in `src/backend/optimizer/util/plancat.c`. The generic logic for clause selectivities is in `src/backend/optimizer/path/clausesel.c`. The operator-specific selectivity functions are mostly found in `src/backend/utils/adt/selfuncs.c`.

VIII. Appendixes

Appendix A. PostgreSQL Error Codes

All messages emitted by the PostgreSQL server are assigned five-character error codes that follow the SQL standard's conventions for "SQLSTATE" codes. Applications that need to know which error condition has occurred should usually test the error code, rather than looking at the textual error message. The error codes are less likely to change across PostgreSQL releases, and also are not subject to change due to localization of error messages. Note that some, but not all, of the error codes produced by PostgreSQL are defined by the SQL standard; some additional error codes for conditions not defined by the standard have been invented or borrowed from other databases.

According to the standard, the first two characters of an error code denote a class of errors, while the last three characters indicate a specific condition within that class. Thus, an application that does not recognize the specific error code might still be able to infer what to do from the error class.

Table A-1 lists all the error codes defined in PostgreSQL 9.4.1. (Some are not actually used at present, but are defined by the SQL standard.) The error classes are also shown. For each error class there is a "standard" error code having the last three characters `000`. This code is used only for error conditions that fall within the class but do not have any more-specific code assigned.

The symbol shown in the column "Condition Name" is the condition name to use in PL/pgSQL. Condition names can be written in either upper or lower case. (Note that PL/pgSQL does not recognize warning, as opposed to error, condition names; those are classes 00, 01, and 02.)

For some types of errors, the server reports the name of a database object (a table, table column, data type, or constraint) associated with the error; for example, the name of the unique constraint that caused a `unique_violation` error. Such names are supplied in separate fields of the error report message so that applications need not try to extract them from the possibly-localized human-readable text of the message. As of PostgreSQL 9.3, complete coverage for this feature exists only for errors in SQLSTATE class 23 (integrity constraint violation), but this is likely to be expanded in future.

Table A-1. PostgreSQL Error Codes

Error Code	Condition Name
Class 00 — Successful Completion	
00000	successful_completion
Class 01 — Warning	
01000	warning
0100C	dynamic_result_sets_returned
01008	implicit_zero_bit_padding
01003	null_value_eliminated_in_set_function
01007	privilege_not_granted
01006	privilege_not_revoked
01004	string_data_right_truncation
01P01	deprecated_feature
Class 02 — No Data (this is also a warning class per the SQL standard)	
02000	no_data
02001	no_additional_dynamic_result_sets_returned
Class 03 — SQL Statement Not Yet Complete	

Error Code	Condition Name
03000	sql_statement_not_yet_complete
Class 08 — Connection Exception	
08000	connection_exception
08003	connection_does_not_exist
08006	connection_failure
08001	sqlclient_unable_to_establish_sqlconnection
08004	sqlserver_rejected_establishment_of_sqlconnection
08007	transaction_resolution_unknown
08P01	protocol_violation
Class 09 — Triggered Action Exception	
09000	triggered_action_exception
Class 0A — Feature Not Supported	
0A000	feature_not_supported
Class 0B — Invalid Transaction Initiation	
0B000	invalid_transaction_initiation
Class 0F — Locator Exception	
0F000	locator_exception
0F001	invalid_locator_specification
Class 0L — Invalid Grantor	
0L000	invalid_grantor
0LP01	invalid_grant_operation
Class 0P — Invalid Role Specification	
0P000	invalid_role_specification
Class 0Z — Diagnostics Exception	
0Z000	diagnostics_exception
0Z002	stacked_diagnostics_accessed_without_active_handle
Class 20 — Case Not Found	
20000	case_not_found
Class 21 — Cardinality Violation	
21000	cardinality_violation
Class 22 — Data Exception	
22000	data_exception
2202E	array_subscript_error
22021	character_not_in_repertoire
22008	datetime_field_overflow
22012	division_by_zero
22005	error_in_assignment
2200B	escape_character_conflict
22022	indicator_overflow

Error Code	Condition Name
22015	interval_field_overflow
2201E	invalid_argument_for_logarithm
22014	invalid_argument_for_ntile_function
22016	invalid_argument_for_nth_value_function
2201F	invalid_argument_for_power_function
2201G	invalid_argument_for_width_bucket_function
22018	invalid_character_value_for_cast
22007	invalid_datetime_format
22019	invalid_escape_character
2200D	invalid_escape_octet
22025	invalid_escape_sequence
22P06	nonstandard_use_of_escape_character
22010	invalid_indicator_parameter_value
22023	invalid_parameter_value
2201B	invalid_regular_expression
2201W	invalid_row_count_in_limit_clause
2201X	invalid_row_count_in_result_offset_clause
22009	invalid_time_zone_displacement_value
2200C	invalid_use_of_escape_character
2200G	most_specific_type_mismatch
22004	null_value_not_allowed
22002	null_value_no_indicator_parameter
22003	numeric_value_out_of_range
22026	string_data_length_mismatch
22001	string_data_right_truncation
22011	substring_error
22027	trim_error
22024	unterminated_c_string
2200F	zero_length_character_string
22P01	floating_point_exception
22P02	invalid_text_representation
22P03	invalid_binary_representation
22P04	bad_copy_file_format
22P05	untranslatable_character
2200L	not_an_xml_document
2200M	invalid_xml_document
2200N	invalid_xml_content
2200S	invalid_xml_comment

Error Code	Condition Name
2200T	invalid_xml_processing_instruction
Class 23 — Integrity Constraint Violation	
23000	integrity_constraint_violation
23001	restrict_violation
23502	not_null_violation
23503	foreign_key_violation
23505	unique_violation
23514	check_violation
23P01	exclusion_violation
Class 24 — Invalid Cursor State	
24000	invalid_cursor_state
Class 25 — Invalid Transaction State	
25000	invalid_transaction_state
25001	active_sql_transaction
25002	branch_transaction_already_active
25008	held_cursor_requires_same_isolation_level
25003	inappropriate_access_mode_for_branch_transaction
25004	inappropriate_isolation_level_for_branch_transacti
25005	no_active_sql_transaction_for_branch_transaction
25006	read_only_sql_transaction
25007	schema_and_data_statement_mixing_not_supported
25P01	no_active_sql_transaction
25P02	in_failed_sql_transaction
Class 26 — Invalid SQL Statement Name	
26000	invalid_sql_statement_name
Class 27 — Triggered Data Change Violation	
27000	triggered_data_change_violation
Class 28 — Invalid Authorization Specification	
28000	invalid_authorization_specification
28P01	invalid_password
Class 2B — Dependent Privilege Descriptors Still Exist	
2B000	dependent_privilege_descriptors_still_exist
2BP01	dependent_objects_still_exist
Class 2D — Invalid Transaction Termination	
2D000	invalid_transaction_termination
Class 2F — SQL Routine Exception	
2F000	sql_routine_exception

Error Code	Condition Name
2F005	function_executed_no_return_statement
2F002	modifying_sql_data_not_permitted
2F003	prohibited_sql_statement_attempted
2F004	reading_sql_data_not_permitted
Class 34 — Invalid Cursor Name	
34000	invalid_cursor_name
Class 38 — External Routine Exception	
38000	external_routine_exception
38001	containing_sql_not_permitted
38002	modifying_sql_data_not_permitted
38003	prohibited_sql_statement_attempted
38004	reading_sql_data_not_permitted
Class 39 — External Routine Invocation Exception	
39000	external_routine_invocation_exception
39001	invalid_sqlstate_returned
39004	null_value_not_allowed
39P01	trigger_protocol_violated
39P02	srf_protocol_violated
Class 3B — Savepoint Exception	
3B000	savepoint_exception
3B001	invalid_savepoint_specification
Class 3D — Invalid Catalog Name	
3D000	invalid_catalog_name
Class 3F — Invalid Schema Name	
3F000	invalid_schema_name
Class 40 — Transaction Rollback	
40000	transaction_rollback
40002	transaction_integrity_constraint_violation
40001	serialization_failure
40003	statement_completion_unknown
40P01	deadlock_detected
Class 42 — Syntax Error or Access Rule Violation	
42000	syntax_error_or_access_rule_violation
42601	syntax_error
42501	insufficient_privilege
42846	cannot_coerce
42803	grouping_error
42P20	windowing_error

Error Code	Condition Name
42P19	invalid_recursion
42830	invalid_foreign_key
42602	invalid_name
42622	name_too_long
42939	reserved_name
42804	datatype_mismatch
42P18	indeterminate_datatype
42P21	collation_mismatch
42P22	indeterminate_collation
42809	wrong_object_type
42703	undefined_column
42883	undefined_function
42P01	undefined_table
42P02	undefined_parameter
42704	undefined_object
42701	duplicate_column
42P03	duplicate_cursor
42P04	duplicate_database
42723	duplicate_function
42P05	duplicate_prepared_statement
42P06	duplicate_schema
42P07	duplicate_table
42712	duplicate_alias
42710	duplicate_object
42702	ambiguous_column
42725	ambiguous_function
42P08	ambiguous_parameter
42P09	ambiguous_alias
42P10	invalid_column_reference
42611	invalid_column_definition
42P11	invalid_cursor_definition
42P12	invalid_database_definition
42P13	invalid_function_definition
42P14	invalid_prepared_statement_definition
42P15	invalid_schema_definition
42P16	invalid_table_definition
42P17	invalid_object_definition
Class 44 — WITH CHECK OPTION Violation	
44000	with_check_option_violation
Class 53 — Insufficient Resources	
53000	insufficient_resources

Error Code	Condition Name
53100	disk_full
53200	out_of_memory
53300	too_many_connections
53400	configuration_limit_exceeded
Class 54 — Program Limit Exceeded	
54000	program_limit_exceeded
54001	statement_too_complex
54011	too_many_columns
54023	too_many_arguments
Class 55 — Object Not In Prerequisite State	
55000	object_not_in_prerequisite_state
55006	object_in_use
55P02	cant_change_runtime_param
55P03	lock_not_available
Class 57 — Operator Intervention	
57000	operator_intervention
57014	query_canceled
57P01	admin_shutdown
57P02	crash_shutdown
57P03	cannot_connect_now
57P04	database_dropped
Class 58 — System Error (errors external to PostgreSQL itself)	
58000	system_error
58030	io_error
58P01	undefined_file
58P02	duplicate_file
Class F0 — Configuration File Error	
F0000	config_file_error
F0001	lock_file_exists
Class HV — Foreign Data Wrapper Error (SQL/MED)	
HV000	fdw_error
HV005	fdw_column_name_not_found
HV002	fdw_dynamic_parameter_value_needed
HV010	fdw_function_sequence_error
HV021	fdw_inconsistent_descriptor_information
HV024	fdw_invalid_attribute_value
HV007	fdw_invalid_column_name
HV008	fdw_invalid_column_number
HV004	fdw_invalid_data_type
HV006	fdw_invalid_data_type_descriptors

Error Code	Condition Name
HV091	fdw_invalid_descriptor_field_identifier
HV00B	fdw_invalid_handle
HV00C	fdw_invalid_option_index
HV00D	fdw_invalid_option_name
HV090	fdw_invalid_string_length_or_buffer_length
HV00A	fdw_invalid_string_format
HV009	fdw_invalid_use_of_null_pointer
HV014	fdw_too_many_handles
HV001	fdw_out_of_memory
HV00P	fdw_no_schemas
HV00J	fdw_option_name_not_found
HV00K	fdw_reply_handle
HV00Q	fdw_schema_not_found
HV00R	fdw_table_not_found
HV00L	fdw_unable_to_create_execution
HV00M	fdw_unable_to_create_reply
HV00N	fdw_unable_to_establish_connection
Class P0 — PL/pgSQL Error	
P0000	plpgsql_error
P0001	raise_exception
P0002	no_data_found
P0003	too_many_rows
Class XX — Internal Error	
XX000	internal_error
XX001	data_corrupted
XX002	index_corrupted

Appendix B. Date/Time Support

PostgreSQL uses an internal heuristic parser for all date/time input support. Dates and times are input as strings, and are broken up into distinct fields with a preliminary determination of what kind of information can be in the field. Each field is interpreted and either assigned a numeric value, ignored, or rejected. The parser contains internal lookup tables for all textual fields, including months, days of the week, and time zones.

This appendix includes information on the content of these lookup tables and describes the steps used by the parser to decode dates and times.

B.1. Date/Time Input Interpretation

The date/time type inputs are all decoded using the following procedure.

1. Break the input string into tokens and categorize each token as a string, time, time zone, or number.

    a. If the numeric token contains a colon (`:`), this is a time string. Include all subsequent digits and colons.

    b. If the numeric token contains a dash (`-`), slash (`/`), or two or more dots (`.`), this is a date string which might have a text month. If a date token has already been seen, it is instead interpreted as a time zone name (e.g., `America/New_York`).

    c. If the token is numeric only, then it is either a single field or an ISO 8601 concatenated date (e.g., `19990113` for January 13, 1999) or time (e.g., `141516` for 14:15:16).

    d. If the token starts with a plus (`+`) or minus (`-`), then it is either a numeric time zone or a special field.

2. If the token is a text string, match up with possible strings:

    a. Do a binary-search table lookup for the token as a time zone abbreviation.

    b. If not found, do a similar binary-search table lookup to match the token as either a special string (e.g., `today`), day (e.g., `Thursday`), month (e.g., `January`), or noise word (e.g., `at`, `on`).

    c. If still not found, throw an error.

3. When the token is a number or number field:

    a. If there are eight or six digits, and if no other date fields have been previously read, then interpret as a "concatenated date" (e.g., `19990118` or `990118`). The interpretation is `YYYYMMDD` or `YYMMDD`.

    b. If the token is three digits and a year has already been read, then interpret as day of year.

    c. If four or six digits and a year has already been read, then interpret as a time (`HHMM` or `HHMMSS`).

d. If three or more digits and no date fields have yet been found, interpret as a year (this forces yy-mm-dd ordering of the remaining date fields).

e. Otherwise the date field ordering is assumed to follow the `DateStyle` setting: mm-dd-yy, dd-mm-yy, or yy-mm-dd. Throw an error if a month or day field is found to be out of range.

4. If BC has been specified, negate the year and add one for internal storage. (There is no year zero in the Gregorian calendar, so numerically 1 BC becomes year zero.)

5. If BC was not specified, and if the year field was two digits in length, then adjust the year to four digits. If the field is less than 70, then add 2000, otherwise add 1900.

Tip: Gregorian years AD 1-99 can be entered by using 4 digits with leading zeros (e.g., `0099` is AD 99).

B.2. Date/Time Key Words

Table B-1 shows the tokens that are recognized as names of months.

Table B-1. Month Names

Month	Abbreviations
January	Jan
February	Feb
March	Mar
April	Apr
May	
June	Jun
July	Jul
August	Aug
September	Sep, Sept
October	Oct
November	Nov
December	Dec

Table B-2 shows the tokens that are recognized as names of days of the week.

Table B-2. Day of the Week Names

Day	Abbreviations
Sunday	Sun
Monday	Mon
Tuesday	Tue, Tues
Wednesday	Wed, Weds

Day	Abbreviations
Thursday	Thu, Thur, Thurs
Friday	Fri
Saturday	Sat

Table B-3 shows the tokens that serve various modifier purposes.

Table B-3. Date/Time Field Modifiers

Identifier	Description
AM	Time is before 12:00
AT	Ignored
JULIAN, JD, J	Next field is Julian Date
ON	Ignored
PM	Time is on or after 12:00
T	Next field is time

B.3. Date/Time Configuration Files

Since timezone abbreviations are not well standardized, PostgreSQL provides a means to customize the set of abbreviations accepted by the server. The timezone_abbreviations run-time parameter determines the active set of abbreviations. While this parameter can be altered by any database user, the possible values for it are under the control of the database administrator — they are in fact names of configuration files stored in .../share/timezonesets/ of the installation directory. By adding or altering files in that directory, the administrator can set local policy for timezone abbreviations.

timezone_abbreviations can be set to any file name found in .../share/timezonesets/, if the file's name is entirely alphabetic. (The prohibition against non-alphabetic characters in timezone_abbreviations prevents reading files outside the intended directory, as well as reading editor backup files and other extraneous files.)

A timezone abbreviation file can contain blank lines and comments beginning with #. Non-comment lines must have one of these formats:

```
zone_abbreviation offset
zone_abbreviation offset D
zone_abbreviation time_zone_name
@INCLUDE file_name
@OVERRIDE
```

A *zone_abbreviation* is just the abbreviation being defined. The *offset* is the equivalent offset in seconds from UTC, positive being east from Greenwich and negative being west. For example, -18000 would be five hours west of Greenwich, or North American east coast standard time. D indicates that the zone name represents local daylight-savings time rather than standard time. Alternatively, a *time_zone_name* can be given, in which case that time zone definition is consulted, and the abbreviation's meaning in that zone is used. This alternative is recommended only for abbreviations whose meaning has historically varied, as looking up the meaning is noticeably more expensive than just using a fixed integer value.

The `@INCLUDE` syntax allows inclusion of another file in the `.../share/timezonesets/` directory. Inclusion can be nested, to a limited depth.

The `@OVERRIDE` syntax indicates that subsequent entries in the file can override previous entries (typically, entries obtained from included files). Without this, conflicting definitions of the same timezone abbreviation are considered an error.

In an unmodified installation, the file `Default` contains all the non-conflicting time zone abbreviations for most of the world. Additional files `Australia` and `India` are provided for those regions: these files first include the `Default` file and then add or modify abbreviations as needed.

For reference purposes, a standard installation also contains files `Africa.txt`, `America.txt`, etc, containing information about every time zone abbreviation known to be in use according to the IANA timezone database. The zone name definitions found in these files can be copied and pasted into a custom configuration file as needed. Note that these files cannot be directly referenced as `timezone_abbreviations` settings, because of the dot embedded in their names.

> **Note:** If an error occurs while reading the time zone abbreviation set, no new value is applied and the old set is kept. If the error occurs while starting the database, startup fails.

Caution

Time zone abbreviations defined in the configuration file override non-timezone meanings built into PostgreSQL. For example, the `Australia` configuration file defines `SAT` (for South Australian Standard Time). When this file is active, `SAT` will not be recognized as an abbreviation for Saturday.

Caution

If you modify files in `.../share/timezonesets/`, it is up to you to make backups — a normal database dump will not include this directory.

B.4. History of Units

The SQL standard states that "Within the definition of a 'datetime literal', the 'datetime values' are constrained by the natural rules for dates and times according to the Gregorian calendar". PostgreSQL follows the SQL standard's lead by counting dates exclusively in the Gregorian calendar, even for years before that calendar was in use. This rule is known as the *proleptic Gregorian calendar*.

The Julian calendar was introduced by Julius Caesar in 45 BC. It was in common use in the Western world until the year 1582, when countries started changing to the Gregorian calendar. In the Julian calendar, the tropical year is approximated as 365 1/4 days = 365.25 days. This gives an error of about 1 day in 128 years.

The accumulating calendar error prompted Pope Gregory XIII to reform the calendar in accordance with instructions from the Council of Trent. In the Gregorian calendar, the tropical year is approximated as 365 + 97 / 400 days = 365.2425 days. Thus it takes approximately 3300 years for the tropical year to shift one day with respect to the Gregorian calendar.

The approximation 365+97/400 is achieved by having 97 leap years every 400 years, using the following rules:

Every year divisible by 4 is a leap year.
However, every year divisible by 100 is not a leap year.
However, every year divisible by 400 is a leap year after all.

So, 1700, 1800, 1900, 2100, and 2200 are not leap years. But 1600, 2000, and 2400 are leap years. By contrast, in the older Julian calendar all years divisible by 4 are leap years.

The papal bull of February 1582 decreed that 10 days should be dropped from October 1582 so that 15 October should follow immediately after 4 October. This was observed in Italy, Poland, Portugal, and Spain. Other Catholic countries followed shortly after, but Protestant countries were reluctant to change, and the Greek Orthodox countries didn't change until the start of the 20th century. The reform was observed by Great Britain and its dominions (including what is now the USA) in 1752. Thus 2 September 1752 was followed by 14 September 1752. This is why Unix systems have the `cal` program produce the following:

```
$ cal 9 1752
   September 1752
 S  M Tu  W Th  F  S
       1  2 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30
```

But, of course, this calendar is only valid for Great Britain and dominions, not other places. Since it would be difficult and confusing to try to track the actual calendars that were in use in various places at various times, PostgreSQL does not try, but rather follows the Gregorian calendar rules for all dates, even though this method is not historically accurate.

Different calendars have been developed in various parts of the world, many predating the Gregorian system. For example, the beginnings of the Chinese calendar can be traced back to the 14th century BC. Legend has it that the Emperor Huangdi invented that calendar in 2637 BC. The People's Republic of China uses the Gregorian calendar for civil purposes. The Chinese calendar is used for determining festivals.

The *Julian Date* system is another type of calendar, unrelated to the Julian calendar though it is confusingly named similarly to that calendar. The Julian Date system was invented by the French scholar Joseph Justus Scaliger (1540-1609) and probably takes its name from Scaliger's father, the Italian scholar Julius Caesar Scaliger (1484-1558). In the Julian Date system, each day has a sequential number, starting from JD 0 (which is sometimes called *the* Julian Date). JD 0 corresponds to 1 January 4713 BC in the Julian calendar, or 24 November 4714 BC in the Gregorian calendar. Julian Date counting is most often used by astronomers for labeling their nightly observations, and therefore a date runs from noon UTC to the next noon UTC, rather than from midnight to midnight: JD 0 designates the 24 hours from noon UTC on 24 November 4714 BC to noon UTC on 25 November 4714 BC.

Although PostgreSQL supports Julian Date notation for input and output of dates (and also uses Julian dates for some internal datetime calculations), it does not observe the nicety of having dates run from noon to noon. PostgreSQL treats a Julian Date as running from midnight to midnight.

Appendix C. SQL Key Words

Table C-1 lists all tokens that are key words in the SQL standard and in PostgreSQL 9.4.1. Background information can be found in Section 4.1.1. (For space reasons, only the latest two versions of the SQL standard, and SQL-92 for historical comparison, are included. The differences between those and the other intermediate standard versions are small.)

SQL distinguishes between *reserved* and *non-reserved* key words. According to the standard, reserved key words are the only real key words; they are never allowed as identifiers. Non-reserved key words only have a special meaning in particular contexts and can be used as identifiers in other contexts. Most non-reserved key words are actually the names of built-in tables and functions specified by SQL. The concept of non-reserved key words essentially only exists to declare that some predefined meaning is attached to a word in some contexts.

In the PostgreSQL parser life is a bit more complicated. There are several different classes of tokens ranging from those that can never be used as an identifier to those that have absolutely no special status in the parser as compared to an ordinary identifier. (The latter is usually the case for functions specified by SQL.) Even reserved key words are not completely reserved in PostgreSQL, but can be used as column labels (for example, `SELECT 55 AS CHECK`, even though `CHECK` is a reserved key word).

In Table C-1 in the column for PostgreSQL we classify as "non-reserved" those key words that are explicitly known to the parser but are allowed as column or table names. Some key words that are otherwise non-reserved cannot be used as function or data type names and are marked accordingly. (Most of these words represent built-in functions or data types with special syntax. The function or type is still available but it cannot be redefined by the user.) Labeled "reserved" are those tokens that are not allowed as column or table names. Some reserved key words are allowable as names for functions or data types; this is also shown in the table. If not so marked, a reserved key word is only allowed as an "AS" column label name.

As a general rule, if you get spurious parser errors for commands that contain any of the listed key words as an identifier you should try to quote the identifier to see if the problem goes away.

It is important to understand before studying Table C-1 that the fact that a key word is not reserved in PostgreSQL does not mean that the feature related to the word is not implemented. Conversely, the presence of a key word does not indicate the existence of a feature.

Table C-1. SQL Key Words

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
A		non-reserved	non-reserved	
ABORT	non-reserved			
ABS		reserved	reserved	
ABSENT		non-reserved	non-reserved	
ABSOLUTE	non-reserved	non-reserved	non-reserved	reserved
ACCESS	non-reserved			
ACCORDING		non-reserved	non-reserved	
ACTION	non-reserved	non-reserved	non-reserved	reserved
ADA		non-reserved	non-reserved	non-reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
ADD	non-reserved	non-reserved	non-reserved	reserved
ADMIN	non-reserved	non-reserved	non-reserved	
AFTER	non-reserved	non-reserved	non-reserved	
AGGREGATE	non-reserved			
ALL	reserved	reserved	reserved	reserved
ALLOCATE		reserved	reserved	reserved
ALSO	non-reserved			
ALTER	non-reserved	reserved	reserved	reserved
ALWAYS	non-reserved	non-reserved	non-reserved	
ANALYSE	reserved			
ANALYZE	reserved			
AND	reserved	reserved	reserved	reserved
ANY	reserved	reserved	reserved	reserved
ARE		reserved	reserved	reserved
ARRAY	reserved	reserved	reserved	
ARRAY_AGG		reserved	reserved	
ARRAY_MAX_CARDINALITY		reserved		
AS	reserved	reserved	reserved	reserved
ASC	reserved	non-reserved	non-reserved	reserved
ASENSITIVE		reserved	reserved	
ASSERTION	non-reserved	non-reserved	non-reserved	reserved
ASSIGNMENT	non-reserved	non-reserved	non-reserved	
ASYMMETRIC	reserved	reserved	reserved	
AT	non-reserved	reserved	reserved	reserved
ATOMIC		reserved	reserved	
ATTRIBUTE	non-reserved	non-reserved	non-reserved	
ATTRIBUTES		non-reserved	non-reserved	
AUTHORIZATION	reserved (can be function or type)	reserved	reserved	reserved
AVG		reserved	reserved	reserved
BACKWARD	non-reserved			
BASE64		non-reserved	non-reserved	
BEFORE	non-reserved	non-reserved	non-reserved	
BEGIN	non-reserved	reserved	reserved	reserved
BEGIN_FRAME		reserved		
BEGIN_PARTITION		reserved		
BERNOULLI		non-reserved	non-reserved	
BETWEEN	non-reserved (cannot be function or type)	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
BIGINT	non-reserved (cannot be function or type)	reserved	reserved	
BINARY	reserved (can be function or type)	reserved	reserved	
BIT	non-reserved (cannot be function or type)			reserved
BIT_LENGTH				reserved
BLOB		reserved	reserved	
BLOCKED		non-reserved	non-reserved	
BOM		non-reserved	non-reserved	
BOOLEAN	non-reserved (cannot be function or type)	reserved	reserved	
BOTH	reserved	reserved	reserved	reserved
BREADTH		non-reserved	non-reserved	
BY	non-reserved	reserved	reserved	reserved
C		non-reserved	non-reserved	non-reserved
CACHE	non-reserved			
CALL		reserved	reserved	
CALLED	non-reserved	reserved	reserved	
CARDINALITY		reserved	reserved	
CASCADE	non-reserved	non-reserved	non-reserved	reserved
CASCADED	non-reserved	reserved	reserved	reserved
CASE	reserved	reserved	reserved	reserved
CAST	reserved	reserved	reserved	reserved
CATALOG	non-reserved	non-reserved	non-reserved	reserved
CATALOG_NAME		non-reserved	non-reserved	non-reserved
CEIL		reserved	reserved	
CEILING		reserved	reserved	
CHAIN	non-reserved	non-reserved	non-reserved	
CHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
CHARACTER	non-reserved (cannot be function or type)	reserved	reserved	reserved
CHARACTERISTICS	non-reserved	non-reserved	non-reserved	
CHARACTERS		non-reserved	non-reserved	
CHARACTER_LENGTH		reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
CHARACTER_SET_CATALOG		non-reserved	non-reserved	non-reserved
CHARACTER_SET_NAME		non-reserved	non-reserved	non-reserved
CHARACTER_SET_SCHEMA		non-reserved	non-reserved	non-reserved
CHAR_LENGTH		reserved	reserved	reserved
CHECK	reserved	reserved	reserved	reserved
CHECKPOINT	non-reserved			
CLASS	non-reserved			
CLASS_ORIGIN		non-reserved	non-reserved	non-reserved
CLOB		reserved	reserved	
CLOSE	non-reserved	reserved	reserved	reserved
CLUSTER	non-reserved			
COALESCE	non-reserved (cannot be function or type)	reserved	reserved	reserved
COBOL		non-reserved	non-reserved	non-reserved
COLLATE	reserved	reserved	reserved	reserved
COLLATION	reserved (can be function or type)	non-reserved	non-reserved	reserved
COLLATION_CATALOG		non-reserved	non-reserved	non-reserved
COLLATION_NAME		non-reserved	non-reserved	non-reserved
COLLATION_SCHEMA		non-reserved	non-reserved	non-reserved
COLLECT		reserved	reserved	
COLUMN	reserved	reserved	reserved	reserved
COLUMNS		non-reserved	non-reserved	
COLUMN_NAME		non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION		non-reserved	non-reserved	non-reserved
COMMAND_FUNCTION_CODE		non-reserved	non-reserved	
COMMENT	non-reserved			
COMMENTS	non-reserved			
COMMIT	non-reserved	reserved	reserved	reserved
COMMITTED	non-reserved	non-reserved	non-reserved	non-reserved
CONCURRENTLY	reserved (can be function or type)			
CONDITION		reserved	reserved	
CONDITION_NUMBER		non-reserved	non-reserved	non-reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
CONFIGURATION	non-reserved			
CONNECT		reserved	reserved	reserved
CONNECTION	non-reserved	non-reserved	non-reserved	reserved
CONNECTION_NAME		non-reserved	non-reserved	non-reserved
CONSTRAINT	reserved	reserved	reserved	reserved
CONSTRAINTS	non-reserved	non-reserved	non-reserved	reserved
CONSTRAINT_CATALOG		non-reserved	non-reserved	non-reserved
CONSTRAINT_NAME		non-reserved	non-reserved	non-reserved
CONSTRAINT_SCHEMA		non-reserved	non-reserved	non-reserved
CONSTRUCTOR		non-reserved	non-reserved	
CONTAINS		reserved	non-reserved	
CONTENT	non-reserved	non-reserved	non-reserved	
CONTINUE	non-reserved	non-reserved	non-reserved	reserved
CONTROL		non-reserved	non-reserved	
CONVERSION	non-reserved			
CONVERT		reserved	reserved	reserved
COPY	non-reserved			
CORR		reserved	reserved	
CORRESPONDING		reserved	reserved	reserved
COST	non-reserved			
COUNT		reserved	reserved	reserved
COVAR_POP		reserved	reserved	
COVAR_SAMP		reserved	reserved	
CREATE	reserved	reserved	reserved	reserved
CROSS	reserved (can be function or type)	reserved	reserved	reserved
CSV	non-reserved			
CUBE		reserved	reserved	
CUME_DIST		reserved	reserved	
CURRENT	non-reserved	reserved	reserved	reserved
CURRENT_CATALOG	reserved	reserved	reserved	
CURRENT_DATE	reserved	reserved	reserved	reserved
CURRENT_DEFAULT_TRANSFORM_GROUP		reserved	reserved	
CURRENT_PATH		reserved	reserved	
CURRENT_ROLE	reserved	reserved	reserved	
CURRENT_ROW		reserved		

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
CURRENT_SCHEMA	reserved (can be function or type)	reserved	reserved	
CURRENT_TIME	reserved	reserved	reserved	reserved
CURRENT_TIMESTAMP	reserved	reserved	reserved	reserved
CURRENT_TRANSFORM_GROUP_FOR_TYPE	reserved	reserved	reserved	
CURRENT_USER	reserved	reserved	reserved	reserved
CURSOR	non-reserved	reserved	reserved	reserved
CURSOR_NAME		non-reserved	non-reserved	non-reserved
CYCLE	non-reserved	reserved	reserved	
DATA	non-reserved	non-reserved	non-reserved	non-reserved
DATABASE	non-reserved			
DATALINK		reserved	reserved	
DATE		reserved	reserved	reserved
DATETIME_INTERVAL_CODE		non-reserved	non-reserved	non-reserved
DATETIME_INTERVAL_PRECISION		non-reserved	non-reserved	non-reserved
DAY	non-reserved	reserved	reserved	reserved
DB		non-reserved	non-reserved	
DEALLOCATE	non-reserved	reserved	reserved	reserved
DEC	non-reserved (cannot be function or type)	reserved	reserved	reserved
DECIMAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
DECLARE	non-reserved	reserved	reserved	reserved
DEFAULT	reserved	reserved	reserved	reserved
DEFAULTS	non-reserved	non-reserved	non-reserved	
DEFERRABLE	reserved	non-reserved	non-reserved	reserved
DEFERRED	non-reserved	non-reserved	non-reserved	reserved
DEFINED		non-reserved	non-reserved	
DEFINER	non-reserved	non-reserved	non-reserved	
DEGREE		non-reserved	non-reserved	
DELETE	non-reserved	reserved	reserved	reserved
DELIMITER	non-reserved			
DELIMITERS	non-reserved			
DENSE_RANK		reserved	reserved	
DEPTH		non-reserved	non-reserved	
DEREF		reserved	reserved	
DERIVED		non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
DESC	reserved	non-reserved	non-reserved	reserved
DESCRIBE		reserved	reserved	reserved
DESCRIPTOR		non-reserved	non-reserved	reserved
DETERMINISTIC		reserved	reserved	
DIAGNOSTICS		non-reserved	non-reserved	reserved
DICTIONARY	non-reserved			
DISABLE	non-reserved			
DISCARD	non-reserved			
DISCONNECT		reserved	reserved	reserved
DISPATCH		non-reserved	non-reserved	
DISTINCT	reserved	reserved	reserved	reserved
DLNEWCOPY		reserved	reserved	
DLPREVIOUSCOPY		reserved	reserved	
DLURLCOMPLETE		reserved	reserved	
DLURLCOMPLETEONLY		reserved	reserved	
DLURLCOMPLETEWRITE		reserved	reserved	
DLURLPATH		reserved	reserved	
DLURLPATHONLY		reserved	reserved	
DLURLPATHWRITE		reserved	reserved	
DLURLSCHEME		reserved	reserved	
DLURLSERVER		reserved	reserved	
DLVALUE		reserved	reserved	
DO	reserved			
DOCUMENT	non-reserved	non-reserved	non-reserved	
DOMAIN	non-reserved	non-reserved	non-reserved	reserved
DOUBLE	non-reserved	reserved	reserved	reserved
DROP	non-reserved	reserved	reserved	reserved
DYNAMIC		reserved	reserved	
DYNAMIC_FUNCTION		non-reserved	non-reserved	non-reserved
DYNAMIC_FUNCTION_CODE		non-reserved	non-reserved	
EACH	non-reserved	reserved	reserved	
ELEMENT		reserved	reserved	
ELSE	reserved	reserved	reserved	reserved
EMPTY		non-reserved	non-reserved	
ENABLE	non-reserved			
ENCODING	non-reserved	non-reserved	non-reserved	
ENCRYPTED	non-reserved			

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
END	reserved	reserved	reserved	reserved
END-EXEC		reserved	reserved	reserved
END_FRAME		reserved		
END_PARTITION		reserved		
ENFORCED		non-reserved		
ENUM	non-reserved			
EQUALS		reserved	non-reserved	
ESCAPE	non-reserved	reserved	reserved	reserved
EVENT	non-reserved			
EVERY		reserved	reserved	
EXCEPT	reserved	reserved	reserved	reserved
EXCEPTION				reserved
EXCLUDE	non-reserved	non-reserved	non-reserved	
EXCLUDING	non-reserved	non-reserved	non-reserved	
EXCLUSIVE	non-reserved			
EXEC		reserved	reserved	reserved
EXECUTE	non-reserved	reserved	reserved	reserved
EXISTS	non-reserved (cannot be function or type)	reserved	reserved	reserved
EXP		reserved	reserved	
EXPLAIN	non-reserved			
EXPRESSION		non-reserved		
EXTENSION	non-reserved			
EXTERNAL	non-reserved	reserved	reserved	reserved
EXTRACT	non-reserved (cannot be function or type)	reserved	reserved	reserved
FALSE	reserved	reserved	reserved	reserved
FAMILY	non-reserved			
FETCH	reserved	reserved	reserved	reserved
FILE		non-reserved	non-reserved	
FILTER	non-reserved	reserved	reserved	
FINAL		non-reserved	non-reserved	
FIRST	non-reserved	non-reserved	non-reserved	reserved
FIRST_VALUE		reserved	reserved	
FLAG		non-reserved	non-reserved	
FLOAT	non-reserved (cannot be function or type)	reserved	reserved	reserved
FLOOR		reserved	reserved	
FOLLOWING	non-reserved	non-reserved	non-reserved	
FOR	reserved	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
FORCE	non-reserved			
FOREIGN	reserved	reserved	reserved	reserved
FORTRAN		non-reserved	non-reserved	non-reserved
FORWARD	non-reserved			
FOUND		non-reserved	non-reserved	reserved
FRAME_ROW		reserved		
FREE		reserved	reserved	
FREEZE	reserved (can be function or type)			
FROM	reserved	reserved	reserved	reserved
FS		non-reserved	non-reserved	
FULL	reserved (can be function or type)	reserved	reserved	reserved
FUNCTION	non-reserved	reserved	reserved	
FUNCTIONS	non-reserved			
FUSION		reserved	reserved	
G		non-reserved	non-reserved	
GENERAL		non-reserved	non-reserved	
GENERATED		non-reserved	non-reserved	
GET		reserved	reserved	reserved
GLOBAL	non-reserved	reserved	reserved	reserved
GO		non-reserved	non-reserved	reserved
GOTO		non-reserved	non-reserved	reserved
GRANT	reserved	reserved	reserved	reserved
GRANTED	non-reserved	non-reserved	non-reserved	
GREATEST	non-reserved (cannot be function or type)			
GROUP	reserved	reserved	reserved	reserved
GROUPING		reserved	reserved	
GROUPS		reserved		
HANDLER	non-reserved			
HAVING	reserved	reserved	reserved	reserved
HEADER	non-reserved			
HEX		non-reserved	non-reserved	
HIERARCHY		non-reserved	non-reserved	
HOLD	non-reserved	reserved	reserved	
HOUR	non-reserved	reserved	reserved	reserved
ID		non-reserved	non-reserved	
IDENTITY	non-reserved	reserved	reserved	reserved
IF	non-reserved			
IGNORE		non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
ILIKE	reserved (can be function or type)			
IMMEDIATE	non-reserved	non-reserved	non-reserved	reserved
IMMEDIATELY		non-reserved		
IMMUTABLE	non-reserved			
IMPLEMENTATION		non-reserved	non-reserved	
IMPLICIT	non-reserved			
IMPORT		reserved	reserved	
IN	reserved	reserved	reserved	reserved
INCLUDING	non-reserved	non-reserved	non-reserved	
INCREMENT	non-reserved	non-reserved	non-reserved	
INDENT		non-reserved	non-reserved	
INDEX	non-reserved			
INDEXES	non-reserved			
INDICATOR		reserved	reserved	reserved
INHERIT	non-reserved			
INHERITS	non-reserved			
INITIALLY	reserved	non-reserved	non-reserved	reserved
INLINE	non-reserved			
INNER	reserved (can be function or type)	reserved	reserved	reserved
INOUT	non-reserved (cannot be function or type)	reserved	reserved	
INPUT	non-reserved	non-reserved	non-reserved	reserved
INSENSITIVE	non-reserved	reserved	reserved	reserved
INSERT	non-reserved	reserved	reserved	reserved
INSTANCE		non-reserved	non-reserved	
INSTANTIABLE		non-reserved	non-reserved	
INSTEAD	non-reserved	non-reserved	non-reserved	
INT	non-reserved (cannot be function or type)	reserved	reserved	reserved
INTEGER	non-reserved (cannot be function or type)	reserved	reserved	reserved
INTEGRITY		non-reserved	non-reserved	
INTERSECT	reserved	reserved	reserved	reserved
INTERSECTION		reserved	reserved	
INTERVAL	non-reserved (cannot be function or type)	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
INTO	reserved	reserved	reserved	reserved
INVOKER	non-reserved	non-reserved	non-reserved	
IS	reserved (can be function or type)	reserved	reserved	reserved
ISNULL	reserved (can be function or type)			
ISOLATION	non-reserved	non-reserved	non-reserved	reserved
JOIN	reserved (can be function or type)	reserved	reserved	reserved
K		non-reserved	non-reserved	
KEY	non-reserved	non-reserved	non-reserved	reserved
KEY_MEMBER		non-reserved	non-reserved	
KEY_TYPE		non-reserved	non-reserved	
LABEL	non-reserved			
LAG		reserved	reserved	
LANGUAGE	non-reserved	reserved	reserved	reserved
LARGE	non-reserved	reserved	reserved	
LAST	non-reserved	non-reserved	non-reserved	reserved
LAST_VALUE		reserved	reserved	
LATERAL	reserved	reserved	reserved	
LC_COLLATE	non-reserved			
LC_CTYPE	non-reserved			
LEAD		reserved	reserved	
LEADING	reserved	reserved	reserved	reserved
LEAKPROOF	non-reserved			
LEAST	non-reserved (cannot be function or type)			
LEFT	reserved (can be function or type)	reserved	reserved	reserved
LENGTH		non-reserved	non-reserved	non-reserved
LEVEL	non-reserved	non-reserved	non-reserved	reserved
LIBRARY		non-reserved	non-reserved	
LIKE	reserved (can be function or type)	reserved	reserved	reserved
LIKE_REGEX		reserved	reserved	
LIMIT	reserved	non-reserved	non-reserved	
LINK		non-reserved	non-reserved	
LISTEN	non-reserved			
LN		reserved	reserved	
LOAD	non-reserved			
LOCAL	non-reserved	reserved	reserved	reserved
LOCALTIME	reserved	reserved	reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
LOCALTIMESTAMP	reserved	reserved	reserved	
LOCATION	non-reserved	non-reserved	non-reserved	
LOCATOR		non-reserved	non-reserved	
LOCK	non-reserved			
LOWER		reserved	reserved	reserved
M		non-reserved	non-reserved	
MAP		non-reserved	non-reserved	
MAPPING	non-reserved	non-reserved	non-reserved	
MATCH	non-reserved	reserved	reserved	reserved
MATCHED		non-reserved	non-reserved	
MATERIALIZED	non-reserved			
MAX		reserved	reserved	reserved
MAXVALUE	non-reserved	non-reserved	non-reserved	
MAX_CARDINALITY			reserved	
MEMBER		reserved	reserved	
MERGE		reserved	reserved	
MESSAGE_LENGTH		non-reserved	non-reserved	non-reserved
MESSAGE_OCTET_LENGTH		non-reserved	non-reserved	non-reserved
MESSAGE_TEXT		non-reserved	non-reserved	non-reserved
METHOD		reserved	reserved	
MIN		reserved	reserved	reserved
MINUTE	non-reserved	reserved	reserved	reserved
MINVALUE	non-reserved	non-reserved	non-reserved	
MOD		reserved	reserved	
MODE	non-reserved			
MODIFIES		reserved	reserved	
MODULE		reserved	reserved	reserved
MONTH	non-reserved	reserved	reserved	reserved
MORE		non-reserved	non-reserved	non-reserved
MOVE	non-reserved			
MULTISET		reserved	reserved	
MUMPS		non-reserved	non-reserved	non-reserved
NAME	non-reserved	non-reserved	non-reserved	non-reserved
NAMES	non-reserved	non-reserved	non-reserved	reserved
NAMESPACE		non-reserved	non-reserved	
NATIONAL	non-reserved (cannot be function or type)	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
NATURAL	reserved (can be function or type)	reserved	reserved	reserved
NCHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
NCLOB		reserved	reserved	
NESTING		non-reserved	non-reserved	
NEW		reserved	reserved	
NEXT	non-reserved	non-reserved	non-reserved	reserved
NFC		non-reserved	non-reserved	
NFD		non-reserved	non-reserved	
NFKC		non-reserved	non-reserved	
NFKD		non-reserved	non-reserved	
NIL		non-reserved	non-reserved	
NO	non-reserved	reserved	reserved	reserved
NONE	non-reserved (cannot be function or type)	reserved	reserved	
NORMALIZE		reserved	reserved	
NORMALIZED		non-reserved	non-reserved	
NOT	reserved	reserved	reserved	reserved
NOTHING	non-reserved			
NOTIFY	non-reserved			
NOTNULL	reserved (can be function or type)			
NOWAIT	non-reserved			
NTH_VALUE		reserved	reserved	
NTILE		reserved	reserved	
NULL	reserved	reserved	reserved	reserved
NULLABLE		non-reserved	non-reserved	non-reserved
NULLIF	non-reserved (cannot be function or type)	reserved	reserved	reserved
NULLS	non-reserved	non-reserved	non-reserved	
NUMBER		non-reserved	non-reserved	non-reserved
NUMERIC	non-reserved (cannot be function or type)	reserved	reserved	reserved
OBJECT	non-reserved	non-reserved	non-reserved	
OCCURRENCES_REGEX		reserved	reserved	
OCTETS		non-reserved	non-reserved	
OCTET_LENGTH		reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
OF	non-reserved	reserved	reserved	reserved
OFF	non-reserved	non-reserved	non-reserved	
OFFSET	reserved	reserved	reserved	
OIDS	non-reserved			
OLD		reserved	reserved	
ON	reserved	reserved	reserved	reserved
ONLY	reserved	reserved	reserved	reserved
OPEN		reserved	reserved	reserved
OPERATOR	non-reserved			
OPTION	non-reserved	non-reserved	non-reserved	reserved
OPTIONS	non-reserved	non-reserved	non-reserved	
OR	reserved	reserved	reserved	reserved
ORDER	reserved	reserved	reserved	reserved
ORDERING		non-reserved	non-reserved	
ORDINALITY	non-reserved	non-reserved	non-reserved	
OTHERS		non-reserved	non-reserved	
OUT	non-reserved (cannot be function or type)	reserved	reserved	
OUTER	reserved (can be function or type)	reserved	reserved	reserved
OUTPUT		non-reserved	non-reserved	reserved
OVER	non-reserved	reserved	reserved	
OVERLAPS	reserved (can be function or type)	reserved	reserved	reserved
OVERLAY	non-reserved (cannot be function or type)	reserved	reserved	
OVERRIDING		non-reserved	non-reserved	
OWNED	non-reserved			
OWNER	non-reserved			
P		non-reserved	non-reserved	
PAD		non-reserved	non-reserved	reserved
PARAMETER		reserved	reserved	
PARAMETER_MODE		non-reserved	non-reserved	
PARAMETER_NAME		non-reserved	non-reserved	
PARAMETER_ORDINAL_POSITION		non-reserved	non-reserved	
PARAMETER_SPECIFIC_CATALOG		non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
PARAMETER_SPECIFIC_NAME		non-reserved	non-reserved	
PARAMETER_SPECIFIC_SCHEMA		non-reserved	non-reserved	
PARSER	non-reserved			
PARTIAL	non-reserved	non-reserved	non-reserved	reserved
PARTITION	non-reserved	reserved	reserved	
PASCAL		non-reserved	non-reserved	non-reserved
PASSING	non-reserved	non-reserved	non-reserved	
PASSTHROUGH		non-reserved	non-reserved	
PASSWORD	non-reserved			
PATH		non-reserved	non-reserved	
PERCENT		reserved		
PERCENTILE_CONT		reserved	reserved	
PERCENTILE_DISC		reserved	reserved	
PERCENT_RANK		reserved	reserved	
PERIOD		reserved		
PERMISSION		non-reserved	non-reserved	
PLACING	reserved	non-reserved	non-reserved	
PLANS	non-reserved			
PLI		non-reserved	non-reserved	non-reserved
PORTION		reserved		
POSITION	non-reserved (cannot be function or type)	reserved	reserved	reserved
POSITION_REGEX		reserved	reserved	
POWER		reserved	reserved	
PRECEDES		reserved		
PRECEDING	non-reserved	non-reserved	non-reserved	
PRECISION	non-reserved (cannot be function or type)	reserved	reserved	reserved
PREPARE	non-reserved	reserved	reserved	reserved
PREPARED	non-reserved			
PRESERVE	non-reserved	non-reserved	non-reserved	reserved
PRIMARY	reserved	reserved	reserved	reserved
PRIOR	non-reserved	non-reserved	non-reserved	reserved
PRIVILEGES	non-reserved	non-reserved	non-reserved	reserved
PROCEDURAL	non-reserved			
PROCEDURE	non-reserved	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
PROGRAM	non-reserved			
PUBLIC		non-reserved	non-reserved	reserved
QUOTE	non-reserved			
RANGE	non-reserved	reserved	reserved	
RANK		reserved	reserved	
READ	non-reserved	non-reserved	non-reserved	reserved
READS		reserved	reserved	
REAL	non-reserved (cannot be function or type)	reserved	reserved	reserved
REASSIGN	non-reserved			
RECHECK	non-reserved			
RECOVERY		non-reserved	non-reserved	
RECURSIVE	non-reserved	reserved	reserved	
REF	non-reserved	reserved	reserved	
REFERENCES	reserved	reserved	reserved	reserved
REFERENCING		reserved	reserved	
REFRESH	non-reserved			
REGR_AVGX		reserved	reserved	
REGR_AVGY		reserved	reserved	
REGR_COUNT		reserved	reserved	
REGR_INTERCEPT		reserved	reserved	
REGR_R2		reserved	reserved	
REGR_SLOPE		reserved	reserved	
REGR_SXX		reserved	reserved	
REGR_SXY		reserved	reserved	
REGR_SYY		reserved	reserved	
REINDEX	non-reserved			
RELATIVE	non-reserved	non-reserved	non-reserved	reserved
RELEASE	non-reserved	reserved	reserved	
RENAME	non-reserved			
REPEATABLE	non-reserved	non-reserved	non-reserved	non-reserved
REPLACE	non-reserved			
REPLICA	non-reserved			
REQUIRING		non-reserved	non-reserved	
RESET	non-reserved			
RESPECT		non-reserved	non-reserved	
RESTART	non-reserved	non-reserved	non-reserved	
RESTORE		non-reserved	non-reserved	
RESTRICT	non-reserved	non-reserved	non-reserved	reserved
RESULT		reserved	reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
RETURN		reserved	reserved	
RETURNED_CARDINALITY		non-reserved	non-reserved	
RETURNED_LENGTH		non-reserved	non-reserved	non-reserved
RETURNED_OCTET_LENGTH		non-reserved	non-reserved	non-reserved
RETURNED_SQLSTATE		non-reserved	non-reserved	non-reserved
RETURNING	reserved	non-reserved	non-reserved	
RETURNS	non-reserved	reserved	reserved	
REVOKE	non-reserved	reserved	reserved	reserved
RIGHT	reserved (can be function or type)	reserved	reserved	reserved
ROLE	non-reserved	non-reserved	non-reserved	
ROLLBACK	non-reserved	reserved	reserved	reserved
ROLLUP		reserved	reserved	
ROUTINE		non-reserved	non-reserved	
ROUTINE_CATALOG		non-reserved	non-reserved	
ROUTINE_NAME		non-reserved	non-reserved	
ROUTINE_SCHEMA		non-reserved	non-reserved	
ROW	non-reserved (cannot be function or type)	reserved	reserved	
ROWS	non-reserved	reserved	reserved	reserved
ROW_COUNT		non-reserved	non-reserved	non-reserved
ROW_NUMBER		reserved	reserved	
RULE	non-reserved			
SAVEPOINT	non-reserved	reserved	reserved	
SCALE		non-reserved	non-reserved	non-reserved
SCHEMA	non-reserved	non-reserved	non-reserved	reserved
SCHEMA_NAME		non-reserved	non-reserved	non-reserved
SCOPE		reserved	reserved	
SCOPE_CATALOG		non-reserved	non-reserved	
SCOPE_NAME		non-reserved	non-reserved	
SCOPE_SCHEMA		non-reserved	non-reserved	
SCROLL	non-reserved	reserved	reserved	reserved
SEARCH	non-reserved	reserved	reserved	
SECOND	non-reserved	reserved	reserved	reserved
SECTION		non-reserved	non-reserved	reserved
SECURITY	non-reserved	non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
SELECT	reserved	reserved	reserved	reserved
SELECTIVE		non-reserved	non-reserved	
SELF		non-reserved	non-reserved	
SENSITIVE		reserved	reserved	
SEQUENCE	non-reserved	non-reserved	non-reserved	
SEQUENCES	non-reserved			
SERIALIZABLE	non-reserved	non-reserved	non-reserved	non-reserved
SERVER	non-reserved	non-reserved	non-reserved	
SERVER_NAME		non-reserved	non-reserved	non-reserved
SESSION	non-reserved	non-reserved	non-reserved	reserved
SESSION_USER	reserved	reserved	reserved	reserved
SET	non-reserved	reserved	reserved	reserved
SETOF	non-reserved (cannot be function or type)			
SETS		non-reserved	non-reserved	
SHARE	non-reserved			
SHOW	non-reserved			
SIMILAR	reserved (can be function or type)	reserved	reserved	
SIMPLE	non-reserved	non-reserved	non-reserved	
SIZE		non-reserved	non-reserved	reserved
SMALLINT	non-reserved (cannot be function or type)	reserved	reserved	reserved
SNAPSHOT	non-reserved			
SOME	reserved	reserved	reserved	reserved
SOURCE		non-reserved	non-reserved	
SPACE		non-reserved	non-reserved	reserved
SPECIFIC		reserved	reserved	
SPECIFICTYPE		reserved	reserved	
SPECIFIC_NAME		non-reserved	non-reserved	
SQL		reserved	reserved	reserved
SQLCODE				reserved
SQLERROR				reserved
SQLEXCEPTION		reserved	reserved	
SQLSTATE		reserved	reserved	reserved
SQLWARNING		reserved	reserved	
SQRT		reserved	reserved	
STABLE	non-reserved			
STANDALONE	non-reserved	non-reserved	non-reserved	
START	non-reserved	reserved	reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
STATE		non-reserved	non-reserved	
STATEMENT	non-reserved	non-reserved	non-reserved	
STATIC		reserved	reserved	
STATISTICS	non-reserved			
STDDEV_POP		reserved	reserved	
STDDEV_SAMP		reserved	reserved	
STDIN	non-reserved			
STDOUT	non-reserved			
STORAGE	non-reserved			
STRICT	non-reserved			
STRIP	non-reserved	non-reserved	non-reserved	
STRUCTURE		non-reserved	non-reserved	
STYLE		non-reserved	non-reserved	
SUBCLASS_ORIGIN		non-reserved	non-reserved	non-reserved
SUBMULTISET		reserved	reserved	
SUBSTRING	non-reserved (cannot be function or type)	reserved	reserved	reserved
SUBSTRING_REGEX		reserved	reserved	
SUCCEEDS		reserved		
SUM		reserved	reserved	reserved
SYMMETRIC	reserved	reserved	reserved	
SYSID	non-reserved			
SYSTEM	non-reserved	reserved	reserved	
SYSTEM_TIME		reserved		
SYSTEM_USER		reserved	reserved	reserved
T		non-reserved	non-reserved	
TABLE	reserved	reserved	reserved	reserved
TABLES	non-reserved			
TABLESAMPLE		reserved	reserved	
TABLESPACE	non-reserved			
TABLE_NAME		non-reserved	non-reserved	non-reserved
TEMP	non-reserved			
TEMPLATE	non-reserved			
TEMPORARY	non-reserved	non-reserved	non-reserved	reserved
TEXT	non-reserved			
THEN	reserved	reserved	reserved	reserved
TIES		non-reserved	non-reserved	
TIME	non-reserved (cannot be function or type)	reserved	reserved	reserved

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
TIMESTAMP	non-reserved (cannot be function or type)	reserved	reserved	reserved
TIMEZONE_HOUR		reserved	reserved	reserved
TIMEZONE_MINUTE		reserved	reserved	reserved
TO	reserved	reserved	reserved	reserved
TOKEN		non-reserved	non-reserved	
TOP_LEVEL_COUNT		non-reserved	non-reserved	
TRAILING	reserved	reserved	reserved	reserved
TRANSACTION	non-reserved	non-reserved	non-reserved	reserved
TRANSACTIONS_COMMITTED		non-reserved	non-reserved	
TRANSACTIONS_ROLLED_BACK		non-reserved	non-reserved	
TRANSACTION_ACTIVE		non-reserved	non-reserved	
TRANSFORM		non-reserved	non-reserved	
TRANSFORMS		non-reserved	non-reserved	
TRANSLATE		reserved	reserved	reserved
TRANSLATE_REGEX		reserved	reserved	
TRANSLATION		reserved	reserved	reserved
TREAT	non-reserved (cannot be function or type)	reserved	reserved	
TRIGGER	non-reserved	reserved	reserved	
TRIGGER_CATALOG		non-reserved	non-reserved	
TRIGGER_NAME		non-reserved	non-reserved	
TRIGGER_SCHEMA		non-reserved	non-reserved	
TRIM	non-reserved (cannot be function or type)	reserved	reserved	reserved
TRIM_ARRAY		reserved	reserved	
TRUE	reserved	reserved	reserved	reserved
TRUNCATE	non-reserved	reserved	reserved	
TRUSTED	non-reserved			
TYPE	non-reserved	non-reserved	non-reserved	non-reserved
TYPES	non-reserved			
UESCAPE		reserved	reserved	
UNBOUNDED	non-reserved	non-reserved	non-reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
UNCOMMITTED	non-reserved	non-reserved	non-reserved	non-reserved
UNDER		non-reserved	non-reserved	
UNENCRYPTED	non-reserved			
UNION	reserved	reserved	reserved	reserved
UNIQUE	reserved	reserved	reserved	reserved
UNKNOWN	non-reserved	reserved	reserved	reserved
UNLINK		non-reserved	non-reserved	
UNLISTEN	non-reserved			
UNLOGGED	non-reserved			
UNNAMED		non-reserved	non-reserved	non-reserved
UNNEST		reserved	reserved	
UNTIL	non-reserved			
UNTYPED		non-reserved	non-reserved	
UPDATE	non-reserved	reserved	reserved	reserved
UPPER		reserved	reserved	reserved
URI		non-reserved	non-reserved	
USAGE		non-reserved	non-reserved	reserved
USER	reserved	reserved	reserved	reserved
USER_DEFINED_TYPE_CATALOG		non-reserved	non-reserved	
USER_DEFINED_TYPE_CODE		non-reserved	non-reserved	
USER_DEFINED_TYPE_NAME		non-reserved	non-reserved	
USER_DEFINED_TYPE_SCHEMA		non-reserved	non-reserved	
USING	reserved	reserved	reserved	reserved
VACUUM	non-reserved			
VALID	non-reserved	non-reserved	non-reserved	
VALIDATE	non-reserved			
VALIDATOR	non-reserved			
VALUE	non-reserved	reserved	reserved	reserved
VALUES	non-reserved (cannot be function or type)	reserved	reserved	reserved
VALUE_OF		reserved		
VARBINARY		reserved	reserved	
VARCHAR	non-reserved (cannot be function or type)	reserved	reserved	reserved
VARIADIC	reserved			
VARYING	non-reserved	reserved	reserved	reserved
VAR_POP		reserved	reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
VAR_SAMP		reserved	reserved	
VERBOSE	reserved (can be function or type)			
VERSION	non-reserved	non-reserved	non-reserved	
VERSIONING		reserved		
VIEW	non-reserved	non-reserved	non-reserved	reserved
VIEWS	non-reserved			
VOLATILE	non-reserved			
WHEN	reserved	reserved	reserved	reserved
WHENEVER		reserved	reserved	reserved
WHERE	reserved	reserved	reserved	reserved
WHITESPACE	non-reserved	non-reserved	non-reserved	
WIDTH_BUCKET		reserved	reserved	
WINDOW	reserved	reserved	reserved	
WITH	reserved	reserved	reserved	reserved
WITHIN	non-reserved	reserved	reserved	
WITHOUT	non-reserved	reserved	reserved	
WORK	non-reserved	non-reserved	non-reserved	reserved
WRAPPER	non-reserved	non-reserved	non-reserved	
WRITE	non-reserved	non-reserved	non-reserved	reserved
XML	non-reserved	reserved	reserved	
XMLAGG		reserved	reserved	
XMLATTRIBUTES	non-reserved (cannot be function or type)	reserved	reserved	
XMLBINARY		reserved	reserved	
XMLCAST		reserved	reserved	
XMLCOMMENT		reserved	reserved	
XMLCONCAT	non-reserved (cannot be function or type)	reserved	reserved	
XMLDECLARATION		non-reserved	non-reserved	
XMLDOCUMENT		reserved	reserved	
XMLELEMENT	non-reserved (cannot be function or type)	reserved	reserved	
XMLEXISTS	non-reserved (cannot be function or type)	reserved	reserved	
XMLFOREST	non-reserved (cannot be function or type)	reserved	reserved	
XMLITERATE		reserved	reserved	

Key Word	PostgreSQL	SQL:2011	SQL:2008	SQL-92
XMLNAMESPACES		reserved	reserved	
XMLPARSE	non-reserved (cannot be function or type)	reserved	reserved	
XMLPI	non-reserved (cannot be function or type)	reserved	reserved	
XMLQUERY		reserved	reserved	
XMLROOT	non-reserved (cannot be function or type)			
XMLSCHEMA		non-reserved	non-reserved	
XMLSERIALIZE	non-reserved (cannot be function or type)	reserved	reserved	
XMLTABLE		reserved	reserved	
XMLTEXT		reserved	reserved	
XMLVALIDATE		reserved	reserved	
YEAR	non-reserved	reserved	reserved	reserved
YES	non-reserved	non-reserved	non-reserved	
ZONE	non-reserved	non-reserved	non-reserved	reserved

Appendix D. SQL Conformance

This section attempts to outline to what extent PostgreSQL conforms to the current SQL standard. The following information is not a full statement of conformance, but it presents the main topics in as much detail as is both reasonable and useful for users.

The formal name of the SQL standard is ISO/IEC 9075 “Database Language SQL”. A revised version of the standard is released from time to time; the most recent update appearing in 2011. The 2011 version is referred to as ISO/IEC 9075:2011, or simply as SQL:2011. The versions prior to that were SQL:2008, SQL:2003, SQL:1999, and SQL-92. Each version replaces the previous one, so claims of conformance to earlier versions have no official merit. PostgreSQL development aims for conformance with the latest official version of the standard where such conformance does not contradict traditional features or common sense. Many of the features required by the SQL standard are supported, though sometimes with slightly differing syntax or function. Further moves towards conformance can be expected over time.

SQL-92 defined three feature sets for conformance: Entry, Intermediate, and Full. Most database management systems claiming SQL standard conformance were conforming at only the Entry level, since the entire set of features in the Intermediate and Full levels was either too voluminous or in conflict with legacy behaviors.

Starting with SQL:1999, the SQL standard defines a large set of individual features rather than the ineffectively broad three levels found in SQL-92. A large subset of these features represents the “Core” features, which every conforming SQL implementation must supply. The rest of the features are purely optional. Some optional features are grouped together to form “packages”, which SQL implementations can claim conformance to, thus claiming conformance to particular groups of features.

The standard versions beginning with SQL:2003 are also split into a number of parts. Each is known by a shorthand name. Note that these parts are not consecutively numbered.

- ISO/IEC 9075-1 Framework (SQL/Framework)
- ISO/IEC 9075-2 Foundation (SQL/Foundation)
- ISO/IEC 9075-3 Call Level Interface (SQL/CLI)
- ISO/IEC 9075-4 Persistent Stored Modules (SQL/PSM)
- ISO/IEC 9075-9 Management of External Data (SQL/MED)
- ISO/IEC 9075-10 Object Language Bindings (SQL/OLB)
- ISO/IEC 9075-11 Information and Definition Schemas (SQL/Schemata)
- ISO/IEC 9075-13 Routines and Types using the Java Language (SQL/JRT)
- ISO/IEC 9075-14 XML-related specifications (SQL/XML)

The PostgreSQL core covers parts 1, 2, 9, 11, and 14. Part 3 is covered by the ODBC driver, and part 13 is covered by the PL/Java plug-in, but exact conformance is currently not being verified for these components. There are currently no implementations of parts 4 and 10 for PostgreSQL.

PostgreSQL supports most of the major features of SQL:2011. Out of 179 mandatory features required for full Core conformance, PostgreSQL conforms to at least 160. In addition, there is a long list of

supported optional features. It might be worth noting that at the time of writing, no current version of any database management system claims full conformance to Core SQL:2011.

In the following two sections, we provide a list of those features that PostgreSQL supports, followed by a list of the features defined in SQL:2011 which are not yet supported in PostgreSQL. Both of these lists are approximate: There might be minor details that are nonconforming for a feature that is listed as supported, and large parts of an unsupported feature might in fact be implemented. The main body of the documentation always contains the most accurate information about what does and does not work.

> **Note:** Feature codes containing a hyphen are subfeatures. Therefore, if a particular subfeature is not supported, the main feature is listed as unsupported even if some other subfeatures are supported.

D.1. Supported Features

Identifier	Package	Description	Comment
B012		Embedded C	
B021		Direct SQL	
E011	Core	Numeric data types	
E011-01	Core	INTEGER and SMALLINT data types	
E011-02	Core	REAL, DOUBLE PRECISION, and FLOAT data types	
E011-03	Core	DECIMAL and NUMERIC data types	
E011-04	Core	Arithmetic operators	
E011-05	Core	Numeric comparison	
E011-06	Core	Implicit casting among the numeric data types	
E021	Core	Character data types	
E021-01	Core	CHARACTER data type	
E021-02	Core	CHARACTER VARYING data type	
E021-03	Core	Character literals	
E021-04	Core	CHARACTER_LENGTH function	trims trailing spaces from CHARACTER values before counting
E021-05	Core	OCTET_LENGTH function	
E021-06	Core	SUBSTRING function	

Identifier	Package	Description	Comment
E021-07	Core	Character concatenation	
E021-08	Core	UPPER and LOWER functions	
E021-09	Core	TRIM function	
E021-10	Core	Implicit casting among the character string types	
E021-11	Core	POSITION function	
E021-12	Core	Character comparison	
E031	Core	Identifiers	
E031-01	Core	Delimited identifiers	
E031-02	Core	Lower case identifiers	
E031-03	Core	Trailing underscore	
E051	Core	Basic query specification	
E051-01	Core	SELECT DISTINCT	
E051-02	Core	GROUP BY clause	
E051-04	Core	GROUP BY can contain columns not in <select list>	
E051-05	Core	Select list items can be renamed	
E051-06	Core	HAVING clause	
E051-07	Core	Qualified * in select list	
E051-08	Core	Correlation names in the FROM clause	
E051-09	Core	Rename columns in the FROM clause	
E061	Core	Basic predicates and search conditions	
E061-01	Core	Comparison predicate	
E061-02	Core	BETWEEN predicate	
E061-03	Core	IN predicate with list of values	
E061-04	Core	LIKE predicate	
E061-05	Core	LIKE predicate ESCAPE clause	
E061-06	Core	NULL predicate	
E061-07	Core	Quantified comparison predicate	
E061-08	Core	EXISTS predicate	
E061-09	Core	Subqueries in comparison predicate	

Identifier	Package	Description	Comment
E061-11	Core	Subqueries in IN predicate	
E061-12	Core	Subqueries in quantified comparison predicate	
E061-13	Core	Correlated subqueries	
E061-14	Core	Search condition	
E071	Core	Basic query expressions	
E071-01	Core	UNION DISTINCT table operator	
E071-02	Core	UNION ALL table operator	
E071-03	Core	EXCEPT DISTINCT table operator	
E071-05	Core	Columns combined via table operators need not have exactly the same data type	
E071-06	Core	Table operators in subqueries	
E081	Core	Basic Privileges	
E081-01	Core	SELECT privilege	
E081-02	Core	DELETE privilege	
E081-03	Core	INSERT privilege at the table level	
E081-04	Core	UPDATE privilege at the table level	
E081-05	Core	UPDATE privilege at the column level	
E081-06	Core	REFERENCES privilege at the table level	
E081-07	Core	REFERENCES privilege at the column level	
E081-08	Core	WITH GRANT OPTION	
E081-09	Core	USAGE privilege	
E081-10	Core	EXECUTE privilege	
E091	Core	Set functions	
E091-01	Core	AVG	
E091-02	Core	COUNT	
E091-03	Core	MAX	
E091-04	Core	MIN	

Identifier	Package	Description	Comment
E091-05	Core	SUM	
E091-06	Core	ALL quantifier	
E091-07	Core	DISTINCT quantifier	
E101	Core	Basic data manipulation	
E101-01	Core	INSERT statement	
E101-03	Core	Searched UPDATE statement	
E101-04	Core	Searched DELETE statement	
E111	Core	Single row SELECT statement	
E121	Core	Basic cursor support	
E121-01	Core	DECLARE CURSOR	
E121-02	Core	ORDER BY columns need not be in select list	
E121-03	Core	Value expressions in ORDER BY clause	
E121-04	Core	OPEN statement	
E121-06	Core	Positioned UPDATE statement	
E121-07	Core	Positioned DELETE statement	
E121-08	Core	CLOSE statement	
E121-10	Core	FETCH statement implicit NEXT	
E121-17	Core	WITH HOLD cursors	
E131	Core	Null value support (nulls in lieu of values)	
E141	Core	Basic integrity constraints	
E141-01	Core	NOT NULL constraints	
E141-02	Core	UNIQUE constraints of NOT NULL columns	
E141-03	Core	PRIMARY KEY constraints	
E141-04	Core	Basic FOREIGN KEY constraint with the NO ACTION default for both referential delete action and referential update action	
E141-06	Core	CHECK constraints	

Identifier	Package	Description	Comment
E141-07	Core	Column defaults	
E141-08	Core	NOT NULL inferred on PRIMARY KEY	
E141-10	Core	Names in a foreign key can be specified in any order	
E151	Core	Transaction support	
E151-01	Core	COMMIT statement	
E151-02	Core	ROLLBACK statement	
E152	Core	Basic SET TRANSACTION statement	
E152-01	Core	SET TRANSACTION statement: ISOLATION LEVEL SERIALIZABLE clause	
E152-02	Core	SET TRANSACTION statement: READ ONLY and READ WRITE clauses	
E153	Core	Updatable queries with subqueries	
E161	Core	SQL comments using leading double minus	
E171	Core	SQLSTATE support	
F021	Core	Basic information schema	
F021-01	Core	COLUMNS view	
F021-02	Core	TABLES view	
F021-03	Core	VIEWS view	
F021-04	Core	TABLE_CONSTRAINTS view	
F021-05	Core	REFERENTIAL_CONSTRAINTS view	
F021-06	Core	CHECK_CONSTRAINTS view	
F031	Core	Basic schema manipulation	
F031-01	Core	CREATE TABLE statement to create persistent base tables	
F031-02	Core	CREATE VIEW statement	
F031-03	Core	GRANT statement	

Identifier	Package	Description	Comment
F031-04	Core	ALTER TABLE statement: ADD COLUMN clause	
F031-13	Core	DROP TABLE statement: RESTRICT clause	
F031-16	Core	DROP VIEW statement: RESTRICT clause	
F031-19	Core	REVOKE statement: RESTRICT clause	
F032		CASCADE drop behavior	
F033		ALTER TABLE statement: DROP COLUMN clause	
F034		Extended REVOKE statement	
F034-01		REVOKE statement performed by other than the owner of a schema object	
F034-02		REVOKE statement: GRANT OPTION FOR clause	
F034-03		REVOKE statement to revoke a privilege that the grantee has WITH GRANT OPTION	
F041	Core	Basic joined table	
F041-01	Core	Inner join (but not necessarily the INNER keyword)	
F041-02	Core	INNER keyword	
F041-03	Core	LEFT OUTER JOIN	
F041-04	Core	RIGHT OUTER JOIN	
F041-05	Core	Outer joins can be nested	
F041-07	Core	The inner table in a left or right outer join can also be used in an inner join	
F041-08	Core	All comparison operators are supported (rather than just =)	
F051	Core	Basic date and time	

Identifier	Package	Description	Comment
F051-01	Core	DATE data type (including support of DATE literal)	
F051-02	Core	TIME data type (including support of TIME literal) with fractional seconds precision of at least 0	
F051-03	Core	TIMESTAMP data type (including support of TIMESTAMP literal) with fractional seconds precision of at least 0 and 6	
F051-04	Core	Comparison predicate on DATE, TIME, and TIMESTAMP data types	
F051-05	Core	Explicit CAST between datetime types and character string types	
F051-06	Core	CURRENT_DATE	
F051-07	Core	LOCALTIME	
F051-08	Core	LOCALTIMESTAMP	
F052	Enhanced datetime facilities	Intervals and datetime arithmetic	
F053		OVERLAPS predicate	
F081	Core	UNION and EXCEPT in views	
F111		Isolation levels other than SERIALIZABLE	
F111-01		READ UNCOMMITTED isolation level	
F111-02		READ COMMITTED isolation level	
F111-03		REPEATABLE READ isolation level	
F131	Core	Grouped operations	
F131-01	Core	WHERE, GROUP BY, and HAVING clauses supported in queries with grouped views	
F131-02	Core	Multiple tables supported in queries with grouped views	

Identifier	Package	Description	Comment
F131-03	Core	Set functions supported in queries with grouped views	
F131-04	Core	Subqueries with GROUP BY and HAVING clauses and grouped views	
F131-05	Core	Single row SELECT with GROUP BY and HAVING clauses and grouped views	
F171		Multiple schemas per user	
F191	Enhanced integrity management	Referential delete actions	
F200		TRUNCATE TABLE statement	
F201	Core	CAST function	
F221	Core	Explicit defaults	
F222		INSERT statement: DEFAULT VALUES clause	
F231		Privilege tables	
F231-01		TABLE_PRIVILEGES view	
F231-02		COLUMN_PRIVILEGES view	
F231-03		USAGE_PRIVILEGES view	
F251		Domain support	
F261	Core	CASE expression	
F261-01	Core	Simple CASE	
F261-02	Core	Searched CASE	
F261-03	Core	NULLIF	
F261-04	Core	COALESCE	
F262		Extended CASE expression	
F271		Compound character literals	
F281		LIKE enhancements	
F302		INTERSECT table operator	
F302-01		INTERSECT DISTINCT table operator	

Identifier	Package	Description	Comment
F302-02		INTERSECT ALL table operator	
F304		EXCEPT ALL table operator	
F311-01	Core	CREATE SCHEMA	
F311-02	Core	CREATE TABLE for persistent base tables	
F311-03	Core	CREATE VIEW	
F311-04	Core	CREATE VIEW: WITH CHECK OPTION	
F311-05	Core	GRANT statement	
F321		User authorization	
F361		Subprogram support	
F381		Extended schema manipulation	
F381-01		ALTER TABLE statement: ALTER COLUMN clause	
F381-02		ALTER TABLE statement: ADD CONSTRAINT clause	
F381-03		ALTER TABLE statement: DROP CONSTRAINT clause	
F382		Alter column data type	
F383		Set column not null clause	
F391		Long identifiers	
F392		Unicode escapes in identifiers	
F393		Unicode escapes in literals	
F401		Extended joined table	
F401-01		NATURAL JOIN	
F401-02		FULL OUTER JOIN	
F401-04		CROSS JOIN	
F402		Named column joins for LOBs, arrays, and multisets	
F411	Enhanced datetime facilities	Time zone specification	differences regarding literal interpretation
F421		National character	
F431		Read-only scrollable cursors	

Identifier	Package	Description	Comment
F431-01		FETCH with explicit NEXT	
F431-02		FETCH FIRST	
F431-03		FETCH LAST	
F431-04		FETCH PRIOR	
F431-05		FETCH ABSOLUTE	
F431-06		FETCH RELATIVE	
F441		Extended set function support	
F442		Mixed column references in set functions	
F471	Core	Scalar subquery values	
F481	Core	Expanded NULL predicate	
F491	Enhanced integrity management	Constraint management	
F501	Core	Features and conformance views	
F501-01	Core	SQL_FEATURES view	
F501-02	Core	SQL_SIZING view	
F501-03	Core	SQL_LANGUAGES view	
F502		Enhanced documentation tables	
F502-01		SQL_SIZING_PROFILES view	
F502-02		SQL_IMPLEMENTATION_INFO view	
F502-03		SQL_PACKAGES view	
F531		Temporary tables	
F555	Enhanced datetime facilities	Enhanced seconds precision	
F561		Full value expressions	
F571		Truth value tests	
F591		Derived tables	
F611		Indicator data types	
F641		Row and table constructors	
F651		Catalog name qualifiers	
F661		Simple tables	

Identifier	Package	Description	Comment
F672		Retrospective check constraints	
F690		Collation support	but no character set support
F692		Extended collation support	
F701	Enhanced integrity management	Referential update actions	
F711		ALTER domain	
F731		INSERT column privileges	
F751		View CHECK enhancements	
F761		Session management	
F762		CURRENT_CATALOG	
F763		CURRENT_SCHEMA	
F771		Connection management	
F781		Self-referencing operations	
F791		Insensitive cursors	
F801		Full set function	
F850		Top-level <order by clause> in <query expression>	
F851		<order by clause> in subqueries	
F852		Top-level <order by clause> in views	
F855		Nested <order by clause> in <query expression>	
F856		Nested <fetch first clause> in <query expression>	
F857		Top-level <fetch first clause> in <query expression>	
F858		<fetch first clause> in subqueries	
F859		Top-level <fetch first clause> in views	

Identifier	Package	Description	Comment
F860		<fetch first row count> in <fetch first clause>	
F861		Top-level <result offset clause> in <query expression>	
F862		<result offset clause> in subqueries	
F863		Nested <result offset clause> in <query expression>	
F864		Top-level <result offset clause> in views	
F865		<offset row count> in <result offset clause>	
S071	Enhanced object support	SQL paths in function and type name resolution	
S092		Arrays of user-defined types	
S095		Array constructors by query	
S096		Optional array bounds	
S098		ARRAY_AGG	
S111	Enhanced object support	ONLY in query expressions	
S201		SQL-invoked routines on arrays	
S201-01		Array parameters	
S201-02		Array as result type of functions	
S211	Enhanced object support	User-defined cast functions	
T031		BOOLEAN data type	
T071		BIGINT data type	
T121		WITH (excluding RECURSIVE) in query expression	
T122		WITH (excluding RECURSIVE) in subquery	
T131		Recursive query	
T132		Recursive query in subquery	
T141		SIMILAR predicate	
T151		DISTINCT predicate	

Identifier	Package	Description	Comment
T152		DISTINCT predicate with negation	
T171		LIKE clause in table definition	
T172		AS subquery clause in table definition	
T173		Extended LIKE clause in table definition	
T191	Enhanced integrity management	Referential action RESTRICT	
T201	Enhanced integrity management	Comparable data types for referential constraints	
T211-01	Active database, Enhanced integrity management	Triggers activated on UPDATE, INSERT, or DELETE of one base table	
T211-02	Active database, Enhanced integrity management	BEFORE triggers	
T211-03	Active database, Enhanced integrity management	AFTER triggers	
T211-04	Active database, Enhanced integrity management	FOR EACH ROW triggers	
T211-05	Active database, Enhanced integrity management	Ability to specify a search condition that must be true before the trigger is invoked	
T211-07	Active database, Enhanced integrity management	TRIGGER privilege	
T212	Enhanced integrity management	Enhanced trigger capability	
T213		INSTEAD OF triggers	
T231		Sensitive cursors	
T241		START TRANSACTION statement	
T271		Savepoints	
T281		SELECT privilege with column granularity	
T312		OVERLAY function	
T321-01	Core	User-defined functions with no overloading	

Identifier	Package	Description	Comment
T321-03	Core	Function invocation	
T321-06	Core	ROUTINES view	
T321-07	Core	PARAMETERS view	
T323		Explicit security for external routines	
T325		Qualified SQL parameter references	
T331		Basic roles	
T341		Overloading of SQL-invoked functions and procedures	
T351		Bracketed SQL comments (/*...*/ comments)	
T441		ABS and MOD functions	
T461		Symmetric BETWEEN predicate	
T491		LATERAL derived table	
T501		Enhanced EXISTS predicate	
T551		Optional key words for default syntax	
T581		Regular expression substring function	
T591		UNIQUE constraints of possibly null columns	
T614		NTILE function	
T615		LEAD and LAG functions	
T617		FIRST_VALUE and LAST_VALUE function	
T621		Enhanced numeric functions	
T631	Core	IN predicate with one list element	
T651		SQL-schema statements in SQL routines	
T655		Cyclically dependent routines	
X010		XML type	
X011		Arrays of XML type	
X016		Persistent XML values	

Identifier	Package	Description	Comment
X020		XMLConcat	
X031		XMLElement	
X032		XMLForest	
X034		XMLAgg	
X035		XMLAgg: ORDER BY option	
X036		XMLComment	
X037		XMLPI	
X040		Basic table mapping	
X041		Basic table mapping: nulls absent	
X042		Basic table mapping: null as nil	
X043		Basic table mapping: table as forest	
X044		Basic table mapping: table as element	
X045		Basic table mapping: with target namespace	
X046		Basic table mapping: data mapping	
X047		Basic table mapping: metadata mapping	
X048		Basic table mapping: base64 encoding of binary strings	
X049		Basic table mapping: hex encoding of binary strings	
X050		Advanced table mapping	
X051		Advanced table mapping: nulls absent	
X052		Advanced table mapping: null as nil	
X053		Advanced table mapping: table as forest	
X054		Advanced table mapping: table as element	
X055		Advanced table mapping: target namespace	

Identifier	Package	Description	Comment
X056		Advanced table mapping: data mapping	
X057		Advanced table mapping: metadata mapping	
X058		Advanced table mapping: base64 encoding of binary strings	
X059		Advanced table mapping: hex encoding of binary strings	
X060		XMLParse: Character string input and CONTENT option	
X061		XMLParse: Character string input and DOCUMENT option	
X070		XMLSerialize: Character string serialization and CONTENT option	
X071		XMLSerialize: Character string serialization and DOCUMENT option	
X072		XMLSerialize: Character string serialization	
X090		XML document predicate	
X120		XML parameters in SQL routines	
X121		XML parameters in external routines	
X400		Name and identifier mapping	
X410		Alter column data type: XML type	

D.2. Unsupported Features

The following features defined in SQL:2011 are not implemented in this release of PostgreSQL. In a

few cases, equivalent functionality is available.

Identifier	Package	Description	Comment
B011		Embedded Ada	
B013		Embedded COBOL	
B014		Embedded Fortran	
B015		Embedded MUMPS	
B016		Embedded Pascal	
B017		Embedded PL/I	
B031		Basic dynamic SQL	
B032		Extended dynamic SQL	
B032-01		<describe input statement>	
B033		Untyped SQL-invoked function arguments	
B034		Dynamic specification of cursor attributes	
B035		Non-extended descriptor names	
B041		Extensions to embedded SQL exception declarations	
B051		Enhanced execution rights	
B111		Module language Ada	
B112		Module language C	
B113		Module language COBOL	
B114		Module language Fortran	
B115		Module language MUMPS	
B116		Module language Pascal	
B117		Module language PL/I	
B121		Routine language Ada	
B122		Routine language C	
B123		Routine language COBOL	
B124		Routine language Fortran	
B125		Routine language MUMPS	
B126		Routine language Pascal	

Identifier	Package	Description	Comment
B127		Routine language PL/I	
B128		Routine language SQL	
B211		Module language Ada: VARCHAR and NUMERIC support	
B221		Routine language Ada: VARCHAR and NUMERIC support	
E182	Core	Module language	
F054		TIMESTAMP in DATE type precedence list	
F121		Basic diagnostics management	
F121-01		GET DIAGNOSTICS statement	
F121-02		SET TRANSACTION statement: DIAGNOSTICS SIZE clause	
F122		Enhanced diagnostics management	
F123		All diagnostics	
F181	Core	Multiple module support	
F202		TRUNCATE TABLE: identity column restart option	
F263		Comma-separated predicates in simple CASE expression	
F291		UNIQUE predicate	
F301		CORRESPONDING in query expressions	
F311	Core	Schema definition statement	
F312		MERGE statement	
F313		Enhanced MERGE statement	
F314		MERGE statement with DELETE branch	
F341		Usage tables	no ROUTINE_*_USAGE tables
F384		Drop identity property clause	

Identifier	Package	Description	Comment
F385		Drop column generation expression clause	
F386		Set identity column generation clause	
F394		Optional normal form specification	
F403		Partitioned joined tables	
F451		Character set definition	
F461		Named character sets	
F492		Optional table constraint enforcement	
F521	Enhanced integrity management	Assertions	
F671	Enhanced integrity management	Subqueries in CHECK	intentionally omitted
F693		SQL-session and client module collations	
F695		Translation support	
F696		Additional translation documentation	
F721		Deferrable constraints	foreign and unique keys only
F741		Referential MATCH types	no partial match yet
F812	Core	Basic flagging	
F813		Extended flagging	
F821		Local table references	
F831		Full cursor update	
F831-01		Updatable scrollable cursors	
F831-02		Updatable ordered cursors	
F841		LIKE_REGEX predicate	
F842		OCCURENCES_REGEX function	
F843		POSITION_REGEX function	
F844		SUBSTRING_REGEX function	
F845		TRANSLATE_REGEX function	

Identifier	Package	Description	Comment
F846		Octet support in regular expression operators	
F847		Nonconstant regular expressions	
F866		FETCH FIRST clause: PERCENT option	
F867		FETCH FIRST clause: WITH TIES option	
S011	Core	Distinct data types	
S011-01	Core	USER_DEFINED_TYPES view	
S023	Basic object support	Basic structured types	
S024	Enhanced object support	Enhanced structured types	
S025		Final structured types	
S026		Self-referencing structured types	
S027		Create method by specific method name	
S028		Permutable UDT options list	
S041	Basic object support	Basic reference types	
S043	Enhanced object support	Enhanced reference types	
S051	Basic object support	Create table of type	partially supported
S081	Enhanced object support	Subtables	
S091		Basic array support	partially supported
S091-01		Arrays of built-in data types	
S091-02		Arrays of distinct types	
S091-03		Array expressions	
S094		Arrays of reference types	
S097		Array element assignment	
S151	Basic object support	Type predicate	
S161	Enhanced object support	Subtype treatment	
S162		Subtype treatment for references	
S202		SQL-invoked routines on multisets	

Identifier	Package	Description	Comment
S231	Enhanced object support	Structured type locators	
S232		Array locators	
S233		Multiset locators	
S241		Transform functions	
S242		Alter transform statement	
S251		User-defined orderings	
S261		Specific type method	
S271		Basic multiset support	
S272		Multisets of user-defined types	
S274		Multisets of reference types	
S275		Advanced multiset support	
S281		Nested collection types	
S291		Unique constraint on entire row	
S301		Enhanced UNNEST	
S401		Distinct types based on array types	
S402		Distinct types based on distinct types	
S403		ARRAY_MAX_CARDINALITY	
S404		TRIM_ARRAY	
T011		Timestamp in Information Schema	
T021		BINARY and VARBINARY data types	
T022		Advanced support for BINARY and VARBINARY data types	
T023		Compound binary literal	
T024		Spaces in binary literals	
T041	Basic object support	Basic LOB data type support	
T041-01	Basic object support	BLOB data type	
T041-02	Basic object support	CLOB data type	

Identifier	Package	Description	Comment
T041-03	Basic object support	POSITION, LENGTH, LOWER, TRIM, UPPER, and SUBSTRING functions for LOB data types	
T041-04	Basic object support	Concatenation of LOB data types	
T041-05	Basic object support	LOB locator: non-holdable	
T042		Extended LOB data type support	
T043		Multiplier T	
T044		Multiplier P	
T051		Row types	
T052		MAX and MIN for row types	
T053		Explicit aliases for all-fields reference	
T061		UCS support	
T101		Enhanced nullability determination	
T111		Updatable joins, unions, and columns	
T174		Identity columns	
T175		Generated columns	
T176		Sequence generator support	
T177		Sequence generator support: simple restart option	
T178		Identity columns: simple restart option	
T180		System-versioned tables	
T181		Application-time period tables	
T211	Active database, Enhanced integrity management	Basic trigger capability	
T211-06	Active database, Enhanced integrity management	Support for run-time rules for the interaction of triggers and constraints	

Identifier	Package	Description	Comment
T211-08	Active database, Enhanced integrity management	Multiple triggers for the same event are executed in the order in which they were created in the catalog	intentionally omitted
T251		SET TRANSACTION statement: LOCAL option	
T261		Chained transactions	
T272		Enhanced savepoint management	
T285		Enhanced derived column names	
T301		Functional dependencies	partially supported
T321	Core	Basic SQL-invoked routines	
T321-02	Core	User-defined stored procedures with no overloading	
T321-04	Core	CALL statement	
T321-05	Core	RETURN statement	
T322	PSM	Declared data type attributes	
T324		Explicit security for SQL routines	
T326		Table functions	
T332		Extended roles	mostly supported
T431	OLAP	Extended grouping capabilities	
T432		Nested and concatenated GROUPING SETS	
T433		Multiargument GROUPING function	
T434		GROUP BY DISTINCT	
T471		Result sets return value	
T472		DESCRIBE CURSOR	
T495		Combined data change and retrieval	different syntax
T502		Period predicates	
T511		Transaction counts	
T521		Named arguments in CALL statement	

Identifier	Package	Description	Comment
T522		Default values for IN parameters of SQL-invoked procedures	
T541		Updatable table references	
T561		Holdable locators	
T571		Array-returning external SQL-invoked functions	
T572		Multiset-returning external SQL-invoked functions	
T601		Local cursor references	
T611	OLAP	Elementary OLAP operations	most forms supported
T612		Advanced OLAP operations	some forms supported
T613		Sampling	
T616		Null treatment option for LEAD and LAG functions	
T618		NTH_VALUE function	function exists, but some options missing
T619		Nested window functions	
T620		WINDOW clause: GROUPS option	
T641		Multiple column assignment	only some syntax variants supported
T652		SQL-dynamic statements in SQL routines	
T653		SQL-schema statements in external routines	
T654		SQL-dynamic statements in external routines	
M001		Datalinks	
M002		Datalinks via SQL/CLI	
M003		Datalinks via Embedded SQL	
M004		Foreign data support	partially supported

Identifier	Package	Description	Comment
M005		Foreign schema support	
M006		GetSQLString routine	
M007		TransmitRequest	
M009		GetOpts and GetStatistics routines	
M010		Foreign data wrapper support	different API
M011		Datalinks via Ada	
M012		Datalinks via C	
M013		Datalinks via COBOL	
M014		Datalinks via Fortran	
M015		Datalinks via M	
M016		Datalinks via Pascal	
M017		Datalinks via PL/I	
M018		Foreign data wrapper interface routines in Ada	
M019		Foreign data wrapper interface routines in C	different API
M020		Foreign data wrapper interface routines in COBOL	
M021		Foreign data wrapper interface routines in Fortran	
M022		Foreign data wrapper interface routines in MUMPS	
M023		Foreign data wrapper interface routines in Pascal	
M024		Foreign data wrapper interface routines in PL/I	
M030		SQL-server foreign data support	
M031		Foreign data wrapper general routines	
X012		Multisets of XML type	
X013		Distinct types of XML type	
X014		Attributes of XML type	
X015		Fields of XML type	

Identifier	Package	Description	Comment
X025		XMLCast	
X030		XMLDocument	
X038		XMLText	
X065		XMLParse: BLOB input and CONTENT option	
X066		XMLParse: BLOB input and DOCUMENT option	
X068		XMLSerialize: BOM	
X069		XMLSerialize: INDENT	
X073		XMLSerialize: BLOB serialization and CONTENT option	
X074		XMLSerialize: BLOB serialization and DOCUMENT option	
X075		XMLSerialize: BLOB serialization	
X076		XMLSerialize: VERSION	
X077		XMLSerialize: explicit ENCODING option	
X078		XMLSerialize: explicit XML declaration	
X080		Namespaces in XML publishing	
X081		Query-level XML namespace declarations	
X082		XML namespace declarations in DML	
X083		XML namespace declarations in DDL	
X084		XML namespace declarations in compound statements	
X085		Predefined namespace prefixes	
X086		XML namespace declarations in XMLTable	
X091		XML content predicate	
X096		XMLExists	

Identifier	Package	Description	Comment
X100		Host language support for XML: CONTENT option	
X101		Host language support for XML: DOCUMENT option	
X110		Host language support for XML: VARCHAR mapping	
X111		Host language support for XML: CLOB mapping	
X112		Host language support for XML: BLOB mapping	
X113		Host language support for XML: STRIP WHITESPACE option	
X114		Host language support for XML: PRESERVE WHITESPACE option	
X131		Query-level XMLBINARY clause	
X132		XMLBINARY clause in DML	
X133		XMLBINARY clause in DDL	
X134		XMLBINARY clause in compound statements	
X135		XMLBINARY clause in subqueries	
X141		IS VALID predicate: data-driven case	
X142		IS VALID predicate: ACCORDING TO clause	
X143		IS VALID predicate: ELEMENT clause	
X144		IS VALID predicate: schema location	
X145		IS VALID predicate outside check constraints	
X151		IS VALID predicate with DOCUMENT option	

Identifier	Package	Description	Comment
X152		IS VALID predicate with CONTENT option	
X153		IS VALID predicate with SEQUENCE option	
X155		IS VALID predicate: NAMESPACE without ELEMENT clause	
X157		IS VALID predicate: NO NAMESPACE with ELEMENT clause	
X160		Basic Information Schema for registered XML Schemas	
X161		Advanced Information Schema for registered XML Schemas	
X170		XML null handling options	
X171		NIL ON NO CONTENT option	
X181		XML(DOCUMENT(UNTYPED)) type	
X182		XML(DOCUMENT(ANY)) type	
X190		XML(SEQUENCE) type	
X191		XML(DOCUMENT(XMLSCHEMA)) type	
X192		XML(CONTENT(XMLSCHEMA)) type	
X200		XMLQuery	
X201		XMLQuery: RETURNING CONTENT	
X202		XMLQuery: RETURNING SEQUENCE	
X203		XMLQuery: passing a context item	
X204		XMLQuery: initializing an XQuery variable	
X205		XMLQuery: EMPTY ON EMPTY option	

Identifier	Package	Description	Comment
X206		XMLQuery: NULL ON EMPTY option	
X211		XML 1.1 support	
X221		XML passing mechanism BY VALUE	
X222		XML passing mechanism BY REF	
X231		XML(CONTENT(UNTYPED)) type	
X232		XML(CONTENT(ANY)) type	
X241		RETURNING CONTENT in XML publishing	
X242		RETURNING SEQUENCE in XML publishing	
X251		Persistent XML values of XML(DOCUMENT(UNTYPED)) type	
X252		Persistent XML values of XML(DOCUMENT(ANY)) type	
X253		Persistent XML values of XML(CONTENT(UNTYPED)) type	
X254		Persistent XML values of XML(CONTENT(ANY)) type	
X255		Persistent XML values of XML(SEQUENCE) type	
X256		Persistent XML values of XML(DOCUMENT(XMLSCHEMA)) type	
X257		Persistent XML values of XML(CONTENT(XMLSCHEMA)) type	
X260		XML type: ELEMENT clause	

Identifier	Package	Description	Comment
X261		XML type: NAMESPACE without ELEMENT clause	
X263		XML type: NO NAMESPACE with ELEMENT clause	
X264		XML type: schema location	
X271		XMLValidate: data-driven case	
X272		XMLValidate: ACCORDING TO clause	
X273		XMLValidate: ELEMENT clause	
X274		XMLValidate: schema location	
X281		XMLValidate: with DOCUMENT option	
X282		XMLValidate with CONTENT option	
X283		XMLValidate with SEQUENCE option	
X284		XMLValidate NAMESPACE without ELEMENT clause	
X286		XMLValidate: NO NAMESPACE with ELEMENT clause	
X300		XMLTable	
X301		XMLTable: derived column list option	
X302		XMLTable: ordinality column option	
X303		XMLTable: column default option	
X304		XMLTable: passing a context item	
X305		XMLTable: initializing an XQuery variable	

Appendix E. Release Notes

The release notes contain the significant changes in each PostgreSQL release, with major features and migration issues listed at the top. The release notes do not contain changes that affect only a few users or changes that are internal and therefore not user-visible. For example, the optimizer is improved in almost every release, but the improvements are usually observed by users as simply faster queries.

A complete list of changes for each release can be obtained by viewing the Git logs for each release. The `pgsql-committers` email list[1] records all source code changes as well. There is also a web interface[2] that shows changes to specific files.

The name appearing next to each item represents the major developer for that item. Of course all changes involve community discussion and patch review, so each item is truly a community effort.

E.1. Release 9.4.1

Release Date: 2015-02-05

This release contains a variety of fixes from 9.4.0. For information about new features in the 9.4 major release, see Section E.2.

E.1.1. Migration to Version 9.4.1

A dump/restore is not required for those running 9.4.X.

However, if you are a Windows user and are using the "Norwegian (Bokmål)" locale, manual action is needed after the upgrade to replace any "Norwegian (Bokmål)_Norway" or "norwegian-bokmal" locale names stored in PostgreSQL system catalogs with the plain-ASCII alias "Norwegian_Norway". For details see http://wiki.postgresql.org/wiki/Changes_To_Norwegian_Locale

E.1.2. Changes

- Fix buffer overruns in `to_char()` (Bruce Momjian)

  When `to_char()` processes a numeric formatting template calling for a large number of digits, PostgreSQL would read past the end of a buffer. When processing a crafted timestamp formatting template, PostgreSQL would write past the end of a buffer. Either case could crash the server. We have not ruled out the possibility of attacks that lead to privilege escalation, though they seem unlikely. (CVE-2015-0241)

- Fix buffer overrun in replacement `*printf()` functions (Tom Lane)

  PostgreSQL includes a replacement implementation of `printf` and related functions. This code will overrun a stack buffer when formatting a floating point number (conversion specifiers `e`, `E`,

1. http://archives.postgresql.org/pgsql-committers/
2. http://git.postgresql.org/gitweb?p=postgresql.git;a=summary

`f`, `F`, `g` or `G`) with requested precision greater than about 500. This will crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. A database user can trigger such a buffer overrun through the `to_char()` SQL function. While that is the only affected core PostgreSQL functionality, extension modules that use printf-family functions may be at risk as well.

This issue primarily affects PostgreSQL on Windows. PostgreSQL uses the system implementation of these functions where adequate, which it is on other modern platforms. (CVE-2015-0242)

- Fix buffer overruns in `contrib/pgcrypto` (Marko Tiikkaja, Noah Misch)

  Errors in memory size tracking within the `pgcrypto` module permitted stack buffer overruns and improper dependence on the contents of uninitialized memory. The buffer overrun cases can crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. (CVE-2015-0243)

- Fix possible loss of frontend/backend protocol synchronization after an error (Heikki Linnakangas)

  If any error occurred while the server was in the middle of reading a protocol message from the client, it could lose synchronization and incorrectly try to interpret part of the message's data as a new protocol message. An attacker able to submit crafted binary data within a command parameter might succeed in injecting his own SQL commands this way. Statement timeout and query cancellation are the most likely sources of errors triggering this scenario. Particularly vulnerable are applications that use a timeout and also submit arbitrary user-crafted data as binary query parameters. Disabling statement timeout will reduce, but not eliminate, the risk of exploit. Our thanks to Emil Lenngren for reporting this issue. (CVE-2015-0244)

- Fix information leak via constraint-violation error messages (Stephen Frost)

  Some server error messages show the values of columns that violate a constraint, such as a unique constraint. If the user does not have `SELECT` privilege on all columns of the table, this could mean exposing values that the user should not be able to see. Adjust the code so that values are displayed only when they came from the SQL command or could be selected by the user. (CVE-2014-8161)

- Lock down regression testing's temporary installations on Windows (Noah Misch)

  Use SSPI authentication to allow connections only from the OS user who launched the test suite. This closes on Windows the same vulnerability previously closed on other platforms, namely that other users might be able to connect to the test postmaster. (CVE-2014-0067)

- Cope with the Windows locale named "Norwegian (Bokmål)" (Heikki Linnakangas)

  Non-ASCII locale names are problematic since it's not clear what encoding they should be represented in. Map the troublesome locale name to a plain-ASCII alias, "Norwegian_Norway".

  9.4.0 mapped the troublesome name to "norwegian-bokmal", but that turns out not to work on all Windows configurations. "Norwegian_Norway" is now recommended instead.

- Fix use-of-already-freed-memory problem in EvalPlanQual processing (Tom Lane)

  In `READ COMMITTED` mode, queries that lock or update recently-updated rows could crash as a result of this bug.

- Avoid possible deadlock while trying to acquire tuple locks in EvalPlanQual processing (Álvaro Herrera, Mark Kirkwood)

- Fix failure to wait when a transaction tries to acquire a `FOR NO KEY EXCLUSIVE` tuple lock, while multiple other transactions currently hold `FOR SHARE` locks (Álvaro Herrera)

- Improve performance of `EXPLAIN` with large range tables (Tom Lane)

- Fix `jsonb` Unicode escape processing, and in consequence disallow `\u0000` (Tom Lane)

Previously, the JSON Unicode escape `\u0000` was accepted and was stored as those six characters; but that is indistinguishable from what is stored for the input `\\u0000`, resulting in ambiguity. Moreover, in cases where de-escaped textual output is expected, such as the `->>` operator, the sequence was printed as `\u0000`, which does not meet the expectation that JSON escaping would be removed. (Consistent behavior would require emitting a zero byte, but PostgreSQL does not support zero bytes embedded in text strings.) 9.4.0 included an ill-advised attempt to improve this situation by adjusting JSON output conversion rules; but of course that could not fix the fundamental ambiguity, and it turned out to break other usages of Unicode escape sequences. Revert that, and to avoid the core problem, reject `\u0000` in `jsonb` input.

If a `jsonb` column contains a `\u0000` value stored with 9.4.0, it will henceforth read out as though it were `\\u0000`, which is the other valid interpretation of the data stored by 9.4.0 for this case.

The `json` type did not have the storage-ambiguity problem, but it did have the problem of inconsistent de-escaped textual output. Therefore `\u0000` will now also be rejected in `json` values when conversion to de-escaped form is required. This change does not break the ability to store `\u0000` in `json` columns so long as no processing is done on the values. This is exactly parallel to the cases in which non-ASCII Unicode escapes are allowed when the database encoding is not UTF8.

- Fix namespace handling in `xpath()` (Ali Akbar)

  Previously, the `xml` value resulting from an `xpath()` call would not have namespace declarations if the namespace declarations were attached to an ancestor element in the input `xml` value, rather than to the specific element being returned. Propagate the ancestral declaration so that the result is correct when considered in isolation.

- Fix assorted oversights in range-operator selectivity estimation (Emre Hasegeli)

  This patch fixes corner-case "unexpected operator NNNN" planner errors, and improves the selectivity estimates for some other cases.

- Revert unintended reduction in maximum size of a GIN index item (Heikki Linnakangas)

  9.4.0 could fail with "index row size exceeds maximum" errors for data that previous versions would accept.

- Fix query-duration memory leak during repeated GIN index rescans (Heikki Linnakangas)

- Fix possible crash when using nonzero `gin_fuzzy_search_limit` (Heikki Linnakangas)

- Assorted fixes for logical decoding (Andres Freund)

- Fix incorrect replay of WAL parameter change records that report changes in the `wal_log_hints` setting (Petr Jalinek)

- Change "pgstat wait timeout" warning message to be LOG level, and rephrase it to be more understandable (Tom Lane)

  This message was originally thought to be essentially a can't-happen case, but it occurs often enough on our slower buildfarm members to be a nuisance. Reduce it to LOG level, and expend a bit more effort on the wording: it now reads "using stale statistics instead of current ones because stats collector is not responding".

- Warn if OS X's `setlocale()` starts an unwanted extra thread inside the postmaster (Noah Misch)

- Fix libpq's behavior when `/etc/passwd` isn't readable (Tom Lane)

  While doing `PQsetdbLogin()`, libpq attempts to ascertain the user's operating system name, which on most Unix platforms involves reading `/etc/passwd`. As of 9.4, failure to do that was treated as a hard error. Restore the previous behavior, which was to fail only if the application does not provide a database role name to connect as. This supports operation in chroot environments that lack an `/etc/passwd` file.

- Improve consistency of parsing of psql's special variables (Tom Lane)

  Allow variant spellings of `on` and `off` (such as `1`/`0`) for `ECHO_HIDDEN` and `ON_ERROR_ROLLBACK`. Report a warning for unrecognized values for `COMP_KEYWORD_CASE`, `ECHO`, `ECHO_HIDDEN`, `HISTCONTROL`, `ON_ERROR_ROLLBACK`, and `VERBOSITY`. Recognize all values for all these variables case-insensitively; previously there was a mishmash of case-sensitive and case-insensitive behaviors.

- Fix pg_dump to handle comments on event triggers without failing (Tom Lane)

- Allow parallel pg_dump to use `--serializable-deferrable` (Kevin Grittner)

- Prevent WAL files created by `pg_basebackup -x/-X` from being archived again when the standby is promoted (Andres Freund)

- Handle unexpected query results, especially NULLs, safely in `contrib/tablefunc`'s `connectby()` (Michael Paquier)

  `connectby()` previously crashed if it encountered a NULL key value. It now prints that row but doesn't recurse further.

- Numerous cleanups of warnings from Coverity static code analyzer (Andres Freund, Tatsuo Ishii, Marko Kreen, Tom Lane, Michael Paquier)

  These changes are mostly cosmetic but in some cases fix corner-case bugs, for example a crash rather than a proper error report after an out-of-memory failure. None are believed to represent security issues.

- Allow `CFLAGS` from configure's environment to override automatically-supplied `CFLAGS` (Tom Lane)

  Previously, configure would add any switches that it chose of its own accord to the end of the user-specified `CFLAGS` string. Since most compilers process switches left-to-right, this meant that configure's choices would override the user-specified flags in case of conflicts. That should work the other way around, so adjust the logic to put the user's string at the end not the beginning.

- Make pg_regress remove any temporary installation it created upon successful exit (Tom Lane)

  This results in a very substantial reduction in disk space usage during `make check-world`, since that sequence involves creation of numerous temporary installations.

- Add CST (China Standard Time) to our lists of timezone abbreviations (Tom Lane)

- Update time zone data files to tzdata release 2015a for DST law changes in Chile and Mexico, plus historical changes in Iceland.

E.2. Release 9.4

Release Date: 2014-12-18

E.2.1. Overview

Major enhancements in PostgreSQL 9.4 include:

- Add `jsonb`, a more capable and efficient data type for storing JSON data

- Add new SQL command ALTER SYSTEM for changing `postgresql.conf` configuration file entries
- Reduce lock strength for some ALTER TABLE commands
- Allow materialized views to be refreshed without blocking concurrent reads
- Add support for logical decoding of WAL data, to allow database changes to be streamed out in a customizable format
- Allow background worker processes to be dynamically registered, started and terminated

The above items are explained in more detail in the sections below.

E.2.2. Migration to Version 9.4

A dump/restore using pg_dumpall, or use of pg_upgrade, is required for those wishing to migrate data from any previous release.

Version 9.4 contains a number of changes that may affect compatibility with previous releases. Observe the following incompatibilities:

- Tighten checks for multidimensional array input (Bruce Momjian)

  Previously, an input array string that started with a single-element sub-array could later contain multi-element sub-arrays, e.g. `'{{1}, {2,3}}'::int[]` would be accepted.

- When converting values of type `date`, `timestamp` or `timestamptz` to `JSON`, render the values in a format compliant with ISO 8601 (Andrew Dunstan)

  Previously such values were rendered according to the current DateStyle setting; but many JSON processors require timestamps to be in ISO 8601 format. If necessary, the previous behavior can be obtained by explicitly casting the datetime value to `text` before passing it to the JSON conversion function.

- The `json #> text[]` path extraction operator now returns its lefthand input, not NULL, if the array is empty (Tom Lane)

  This is consistent with the notion that this represents zero applications of the simple field/element extraction operator `->`. Similarly, `json #>> text[]` with an empty array merely coerces its lefthand input to text.

- Corner cases in the `JSON` field/element/path extraction operators now return NULL rather than raising an error (Tom Lane)

  For example, applying field extraction to a JSON array now yields NULL not an error. This is more consistent (since some comparable cases such as no-such-field already returned NULL), and it makes it safe to create expression indexes that use these operators, since they will now not throw errors for any valid JSON input.

- Cause consecutive whitespace in `to_timestamp()` and `to_date()` format strings to consume a corresponding number of characters in the input string (whitespace or not), then conditionally consume adjacent whitespace, if not in `FX` mode (Jeevan Chalke)

  Previously, consecutive whitespace characters in a non-`FX` format string behaved like a single whitespace character and consumed all adjacent whitespace in the input string. For example, previously a format string of three spaces would consume only the first space in `'  12'`, but it will now consume all three characters.

- Fix `ts_rank_cd()` to ignore stripped lexemes (Alex Hill)

Previously, stripped lexemes were treated as if they had a default location, producing a rank of dubious usefulness.

- For functions declared to take `VARIADIC "any"`, an actual parameter marked as `VARIADIC` must be of a determinable array type (Pavel Stehule)

  Such parameters can no longer be written as an undecorated string literal or `NULL`; a cast to an appropriate array data type will now be required. Note that this does not affect parameters not marked `VARIADIC`.

- Ensure that whole-row variables expose the expected column names to functions that pay attention to column names within composite arguments (Tom Lane)

  Constructs like `row_to_json(tab.*)` now always emit column names that match the column aliases visible for table `tab` at the point of the call. In previous releases the emitted column names would sometimes be the table's actual column names regardless of any aliases assigned in the query.

- DISCARD now also discards sequence-related state (Fabrízio de Royes Mello, Robert Haas)

- Rename `EXPLAIN ANALYZE`'s "total runtime" output to "execution time" (Tom Lane)

  Now that planning time is also reported, the previous name was confusing.

- `SHOW TIME ZONE` now outputs simple numeric UTC offsets in POSIX timezone format (Tom Lane)

  Previously, such timezone settings were displayed as `interval` values. The new output is properly interpreted by `SET TIME ZONE` when passed as a simple string, whereas the old output required special treatment to be re-parsed correctly.

- Foreign data wrappers that support updating foreign tables must consider the possible presence of `AFTER ROW` triggers (Noah Misch)

  When an `AFTER ROW` trigger is present, all columns of the table must be returned by updating actions, since the trigger might inspect any or all of them. Previously, foreign tables never had triggers, so the FDW might optimize away fetching columns not mentioned in the `RETURNING` clause (if any).

- Prevent `CHECK` constraints from referencing system columns, except `tableoid` (Amit Kapila)

  Previously such check constraints were allowed, but they would often cause errors during restores.

- Use the last specified recovery target parameter if multiple target parameters are specified (Heikki Linnakangas)

  Previously, there was an undocumented precedence order among the `recovery_target_`*`xxx`* parameters.

- On Windows, automatically preserve quotes in command strings supplied by the user (Heikki Linnakangas)

  User commands that did their own quote preservation might need adjustment. This is likely to be an issue for commands used in archive_command, restore_command, and `COPY TO/FROM PROGRAM`.

- Remove catalog column `pg_class.reltoastidxid` (Michael Paquier)

- Remove catalog column `pg_rewrite.ev_attr` (Kevin Grittner)

  Per-column rules have not been supported since PostgreSQL 7.3.

- Remove native support for Kerberos authentication (`--with-krb5`, etc) (Magnus Hagander)

  The supported way to use Kerberos authentication is with GSSAPI. The native code has been deprecated since PostgreSQL 8.3.

- In PL/Python, handle domains over arrays like the underlying array type (Rodolfo Campero)

Previously such values were treated as strings.

- Make libpq's `PQconnectdbParams()` and `PQpingParams()` functions process zero-length strings as defaults (Adrian Vondendriesch)

  Previously, these functions treated zero-length string values as selecting the default in only some cases.

- Change empty arrays returned by the intarray module to be zero-dimensional arrays (Bruce Momjian)

  Previously, empty arrays were returned as zero-length one-dimensional arrays, whose text representation looked the same as zero-dimensional arrays (`{}`), but they acted differently in array operations. intarray's behavior in this area now matches the built-in array operators.

- pg_upgrade now uses `-U` or `--username` to specify the user name (Bruce Momjian)

  Previously this option was spelled `-u` or `--user`, but that was inconsistent with other tools.

E.2.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 9.4 and the previous major release.

E.2.3.1. Server

- Allow background worker processes to be dynamically registered, started and terminated (Robert Haas)

  The new `worker_spi` module shows an example of use of this feature.

- Allow dynamic allocation of shared memory segments (Robert Haas, Amit Kapila)

  This feature is illustrated in the `test_shm_mq` module.

- During crash recovery or immediate shutdown, send uncatchable termination signals (SIGKILL) to child processes that do not shut down promptly (MauMau, Álvaro Herrera)

  This reduces the likelihood of leaving orphaned child processes behind after postmaster shutdown, as well as ensuring that crash recovery can proceed if some child processes have become "stuck".

- Improve randomness of the database system identifier (Tom Lane)

- Make VACUUM properly report dead but not-yet-removable rows to the statistics collector (Hari Babu)

  Previously these were reported as live rows.

E.2.3.1.1. Indexes

- Reduce GIN index size (Alexander Korotkov, Heikki Linnakangas)

  Indexes upgraded via pg_upgrade will work fine but will still be in the old, larger GIN format. Use REINDEX to recreate old GIN indexes in the new format.

- Improve speed of multi-key GIN lookups (Alexander Korotkov, Heikki Linnakangas)

- Add GiST index support for `inet` and `cidr` data types (Emre Hasegeli)

  Such indexes improve subnet and supernet lookups and ordering comparisons.

- Fix rare race condition in B-tree page deletion (Heikki Linnakangas)
- Make the handling of interrupted B-tree page splits more robust (Heikki Linnakangas)

E.2.3.1.2. General Performance

- Allow multiple backends to insert into WAL buffers concurrently (Heikki Linnakangas)

  This improves parallel write performance.
- Conditionally write only the modified portion of updated rows to WAL (Amit Kapila)
- Improve performance of aggregate functions used as window functions (David Rowley, Florian Pflug, Tom Lane)
- Improve speed of aggregates that use `numeric` state values (Hadi Moshayedi)
- Attempt to freeze tuples when tables are rewritten with CLUSTER or `VACUUM FULL` (Robert Haas, Andres Freund)

  This can avoid the need to freeze the tuples in the future.
- Improve speed of COPY with default `nextval()` columns (Simon Riggs)
- Improve speed of accessing many different sequences in the same session (David Rowley)
- Raise hard limit on the number of tuples held in memory during sorting and B-tree index builds (Noah Misch)
- Reduce memory allocated by PL/pgSQL DO blocks (Tom Lane)
- Make the planner more aggressive about extracting restriction clauses from mixed `AND`/`OR` clauses (Tom Lane)
- Disallow pushing volatile `WHERE` clauses down into `DISTINCT` subqueries (Tom Lane)

  Pushing down a `WHERE` clause can produce a more efficient plan overall, but at the cost of evaluating the clause more often than is implied by the text of the query; so don't do it if the clause contains any volatile functions.
- Auto-resize the catalog caches (Heikki Linnakangas)

  This reduces memory consumption for sessions accessing only a few tables, and improves performance for sessions accessing many tables.

E.2.3.1.3. Monitoring

- Add pg_stat_archiver system view to report WAL archiver activity (Gabriele Bartolini)
- Add `n_mod_since_analyze` columns to pg_stat_all_tables and related system views (Mark Kirkwood)

  These columns expose the system's estimate of the number of changed tuples since the table's last ANALYZE. This estimate drives decisions about when to auto-analyze.
- Add `backend_xid` and `backend_xmin` columns to the system view pg_stat_activity, and a `backend_xmin` column to pg_stat_replication (Christian Kruse)

E.2.3.1.4. SSL

- Add support for SSL ECDH key exchange (Marko Kreen)

  This allows use of Elliptic Curve keys for server authentication. Such keys are faster and have better security than RSA keys. The new configuration parameter ssl_ecdh_curve controls which curve is used for ECDH.
- Improve the default ssl_ciphers setting (Marko Kreen)
- By default, the server not the client now controls the preference order of SSL ciphers (Marko Kreen)

  Previously, the order specified by ssl_ciphers was usually ignored in favor of client-side defaults, which are not configurable in most PostgreSQL clients. If desired, the old behavior can be restored via the new configuration parameter ssl_prefer_server_ciphers.
- Make log_connections show SSL encryption information (Andreas Kunert)
- Improve SSL renegotiation handling (Álvaro Herrera)

E.2.3.1.5. Server Settings

- Add new SQL command ALTER SYSTEM for changing `postgresql.conf` configuration file entries (Amit Kapila)

  Previously such settings could only be changed by manually editing `postgresql.conf`.
- Add autovacuum_work_mem configuration parameter to control the amount of memory used by autovacuum workers (Peter Geoghegan)
- Add huge_pages parameter to allow using huge memory pages on Linux (Christian Kruse, Richard Poole, Abhijit Menon-Sen)

  This can improve performance on large-memory systems.
- Add max_worker_processes parameter to limit the number of background workers (Robert Haas)

  This is helpful in configuring a standby server to have the required number of worker processes (the same as the primary).
- Add superuser-only session_preload_libraries parameter to load libraries at session start (Peter Eisentraut)

  In contrast to local_preload_libraries, this parameter can load any shared library, not just those in the `$libdir/plugins` directory.
- Add wal_log_hints parameter to enable WAL logging of hint-bit changes (Sawada Masahiko)

  Hint bit changes are not normally logged, except when checksums are enabled. This is useful for external tools like pg_rewind.
- Increase the default settings of work_mem and maintenance_work_mem by four times (Bruce Momjian)

  The new defaults are 4MB and 64MB respectively.
- Increase the default setting of effective_cache_size to 4GB (Bruce Momjian, Tom Lane)
- Allow `printf`-style space padding to be specified in log_line_prefix (David Rowley)
- Allow terabyte units (`TB`) to be used when specifying configuration variable values (Simon Riggs)

- Show PIDs of lock holders and waiters and improve information about relations in log_lock_waits log messages (Christian Kruse)
- Reduce server logging level when loading shared libraries (Peter Geoghegan)

  The previous level was `LOG`, which was too verbose for libraries loaded per-session.
- On Windows, make `SQL_ASCII`-encoded databases and server processes (e.g., postmaster) emit messages in the character encoding of the server's Windows user locale (Alexander Law, Noah Misch)

  Previously these messages were output in the Windows ANSI code page.

E.2.3.2. Replication and Recovery

- Add replication slots to coordinate activity on streaming standbys with the node they are streaming from (Andres Freund, Robert Haas)

  Replication slots allow preservation of resources like WAL files on the primary until they are no longer needed by standby servers.
- Add recovery parameter recovery_min_apply_delay to delay replication (Robert Haas, Fabrízio de Royes Mello, Simon Riggs)

  Delaying replay on standby servers can be useful for recovering from user errors.
- Add recovery_target option `immediate` to stop WAL recovery as soon as a consistent state is reached (MauMau, Heikki Linnakangas)
- Improve recovery target processing (Heikki Linnakangas)

  The timestamp reported by `pg_last_xact_replay_timestamp()` now reflects already-committed records, not transactions about to be committed. Recovering to a restore point now replays the restore point, rather than stopping just before the restore point.
- `pg_switch_xlog()` now clears any unused trailing space in the old WAL file (Heikki Linnakangas)

  This improves the compression ratio for WAL files.
- Report failure return codes from external recovery commands (Peter Eisentraut)
- Reduce spinlock contention during WAL replay (Heikki Linnakangas)
- Write WAL records of running transactions more frequently (Andres Freund)

  This allows standby servers to start faster and clean up resources more aggressively.

E.2.3.2.1. Logical Decoding

Logical decoding allows database changes to be streamed in a configurable format. The data is read from the WAL and transformed into the desired target format. To implement this feature, the following changes were made:

- Add support for logical decoding of WAL data, to allow database changes to be streamed out in a customizable format (Andres Freund)
- Add new wal_level setting `logical` to enable logical change-set encoding in WAL (Andres Freund)

- Add table-level parameter `REPLICA IDENTITY` to control logical replication (Andres Freund)
- Add relation option `user_catalog_table` to identify user-created tables involved in logical change-set encoding (Andres Freund)
- Add pg_recvlogical application to receive logical-decoding data (Andres Freund)
- Add test_decoding module to illustrate logical decoding at the SQL level (Andres Freund)

E.2.3.3. Queries

- Add `WITH ORDINALITY` syntax to number the rows returned from a set-returning function in the `FROM` clause (Andrew Gierth, David Fetter)

  This is particularly useful for functions like `unnest()`.
- Add `ROWS FROM()` syntax to allow horizontal concatenation of set-returning functions in the `FROM` clause (Andrew Gierth)
- Allow SELECT to have an empty target list (Tom Lane)

  This was added so that views that select from a table with zero columns can be dumped and restored correctly.
- Ensure that `SELECT ... FOR UPDATE NOWAIT` does not wait in corner cases involving already-concurrently-updated tuples (Craig Ringer and Thomas Munro)

E.2.3.4. Utility Commands

- Add `DISCARD SEQUENCES` command to discard cached sequence-related state (Fabrízio de Royes Mello, Robert Haas)

  `DISCARD ALL` will now also discard such information.
- Add `FORCE NULL` option to `COPY FROM`, which causes quoted strings matching the specified null string to be converted to NULLs in `CSV` mode (Ian Barwick, Michael Paquier)

  Without this option, only unquoted matching strings will be imported as null values.
- Issue warnings for commands used outside of transaction blocks when they can have no effect (Bruce Momjian)

  New warnings are issued for `SET LOCAL`, `SET CONSTRAINTS`, `SET TRANSACTION` and `ABORT` when used outside a transaction block.

E.2.3.4.1. EXPLAIN

- Make `EXPLAIN ANALYZE` show planning time (Andreas Karlsson)
- Make `EXPLAIN` show the grouping columns in Agg and Group nodes (Tom Lane)
- Make `EXPLAIN ANALYZE` show exact and lossy block counts in bitmap heap scans (Etsuro Fujita)

E.2.3.4.2. Views

- Allow a materialized view to be refreshed without blocking other sessions from reading the view meanwhile (Kevin Grittner)

  This is done with `REFRESH MATERIALIZED VIEW CONCURRENTLY`.

- Allow views to be automatically updated even if they contain some non-updatable columns (Dean Rasheed)

  Previously the presence of non-updatable output columns such as expressions, literals, and function calls prevented automatic updates. Now `INSERT`s, `UPDATE`s and `DELETE`s are supported, provided that they do not attempt to assign new values to any of the non-updatable columns.

- Allow control over whether `INSERT`s and `UPDATE`s can add rows to an auto-updatable view that would not appear in the view (Dean Rasheed)

  This is controlled with the new CREATE VIEW clause `WITH CHECK OPTION`.

- Allow security barrier views to be automatically updatable (Dean Rasheed)

E.2.3.5. Object Manipulation

- Support triggers on foreign tables (Ronan Dunklau)
- Allow moving groups of objects from one tablespace to another using the `ALL IN TABLESPACE ... SET TABLESPACE` form of ALTER TABLE, ALTER INDEX, or ALTER MATERIALIZED VIEW (Stephen Frost)
- Allow changing foreign key constraint deferrability via ALTER TABLE ... `ALTER CONSTRAINT` (Simon Riggs)
- Reduce lock strength for some ALTER TABLE commands (Simon Riggs, Noah Misch, Robert Haas)

  Specifically, `VALIDATE CONSTRAINT`, `CLUSTER ON`, `SET WITHOUT CLUSTER`, `ALTER COLUMN SET STATISTICS`, `ALTER COLUMN SET (attribute_option)`, `ALTER COLUMN RESET (attribute_option)` no longer require `ACCESS EXCLUSIVE` locks.

- Allow tablespace options to be set in CREATE TABLESPACE (Vik Fearing)

  Formerly these options could only be set via ALTER TABLESPACE.

- Allow CREATE AGGREGATE to define the estimated size of the aggregate's transition state data (Hadi Moshayedi)

  Proper use of this feature allows the planner to better estimate how much memory will be used by aggregates.

- Fix `DROP IF EXISTS` to avoid errors for non-existent objects in more cases (Pavel Stehule, Dean Rasheed)
- Improve how system relations are identified (Andres Freund, Robert Haas)

  Previously, relations once moved into the `pg_catalog` schema could no longer be modified or dropped.

E.2.3.6. Data Types

- Fully implement the `line` data type (Peter Eisentraut)

  The line *segment* data type (`lseg`) has always been fully supported. The previous `line` data type (which was enabled only via a compile-time option) is not binary or dump-compatible with the new implementation.

- Add `pg_lsn` data type to represent a WAL log sequence number (LSN) (Robert Haas, Michael Paquier)

- Allow single-point `polygon`s to be converted to `circle`s (Bruce Momjian)

- Support time zone abbreviations that change UTC offset from time to time (Tom Lane)

  Previously, PostgreSQL assumed that the UTC offset associated with a time zone abbreviation (such as `EST`) never changes in the usage of any particular locale. However this assumption fails in the real world, so introduce the ability for a zone abbreviation to represent a UTC offset that sometimes changes. Update the zone abbreviation definition files to make use of this feature in timezone locales that have changed the UTC offset of their abbreviations since 1970 (according to the IANA timezone database). In such timezones, PostgreSQL will now associate the correct UTC offset with the abbreviation depending on the given date.

- Allow 5+ digit years for non-ISO `timestamp` and `date` strings, where appropriate (Bruce Momjian)

- Add checks for overflow/underflow of `interval` values (Bruce Momjian)

E.2.3.6.1. JSON

- Add `jsonb`, a more capable and efficient data type for storing JSON data (Oleg Bartunov, Teodor Sigaev, Alexander Korotkov, Peter Geoghegan, Andrew Dunstan)

  This new type allows faster access to values within a JSON document, and faster and more useful indexing of JSON columns. Scalar values in `jsonb` documents are stored as appropriate scalar SQL types, and the JSON document structure is pre-parsed rather than being stored as text as in the original `json` data type.

- Add new JSON functions to allow for the construction of arbitrarily complex JSON trees (Andrew Dunstan, Laurence Rowe)

  New functions include `json_array_elements_text()`, `json_build_array()`, `json_object()`, `json_object_agg()`, `json_to_record()`, and `json_to_recordset()`.

- Add `json_typeof()` to return the data type of a `json` value (Andrew Tipton)

E.2.3.7. Functions

- Add `pg_sleep_for(interval)` and `pg_sleep_until(timestamp)` to specify delays more flexibly (Vik Fearing, Julien Rouhaud)

  The existing `pg_sleep()` function only supports delays specified in seconds.

- Add `cardinality()` function for arrays (Marko Tiikkaja)

  This returns the total number of elements in the array, or zero for an array with no elements.

- Add SQL functions to allow large object reads/writes at arbitrary offsets (Pavel Stehule)

- Allow `unnest()` to take multiple arguments, which are individually unnested then horizontally concatenated (Andrew Gierth)
- Add functions to construct `time`s, `date`s, `timestamp`s, `timestamptz`s, and `interval`s from individual values, rather than strings (Pavel Stehule)

  These functions' names are prefixed with `make_`, e.g. `make_date()`.
- Make `to_char()`'s `TZ` format specifier return a useful value for simple numeric time zone offsets (Tom Lane)

  Previously, `to_char(CURRENT_TIMESTAMP, 'TZ')` returned an empty string if the `timezone` was set to a constant like `-4`.
- Add timezone offset format specifier `OF` to `to_char()` (Bruce Momjian)
- Improve the random seed used for `random()` (Honza Horak)
- Tighten validity checking for Unicode code points in `chr(int)` (Tom Lane)

  This function now only accepts values that are valid UTF8 characters according to RFC 3629.

E.2.3.7.1. System Information Functions

- Add functions for looking up objects in `pg_class`, `pg_proc`, `pg_type`, and `pg_operator` that do not generate errors for non-existent objects (Yugo Nagata, Nozomi Anzai, Robert Haas)

  For example, `to_regclass()` does a lookup in `pg_class` similarly to the `regclass` input function, but it returns NULL for a non-existent object instead of failing.
- Add function `pg_filenode_relation()` to allow for more efficient lookup of relation names from filenodes (Andres Freund)
- Add `parameter_default` column to `information_schema.parameters` view (Peter Eisentraut)
- Make `information_schema.schemata` show all accessible schemas (Peter Eisentraut)

  Previously it only showed schemas owned by the current user.

E.2.3.7.2. Aggregates

- Add control over which rows are passed into aggregate functions via the `FILTER` clause (David Fetter)
- Support ordered-set (`WITHIN GROUP`) aggregates (Atri Sharma, Andrew Gierth, Tom Lane)
- Add standard ordered-set aggregates `percentile_cont()`, `percentile_disc()`, `mode()`, `rank()`, `dense_rank()`, `percent_rank()`, and `cume_dist()` (Atri Sharma, Andrew Gierth)
- Support `VARIADIC` aggregate functions (Tom Lane)
- Allow polymorphic aggregates to have non-polymorphic state data types (Tom Lane)

  This allows proper declaration in SQL of aggregates like the built-in aggregate `array_agg()`.

E.2.3.8. Server-Side Languages

- Add event trigger support to PL/Perl and PL/Tcl (Dimitri Fontaine)

- Convert `numeric` values to `decimal` in PL/Python (Szymon Guz, Ronan Dunklau)

  Previously such values were converted to Python `float` values, risking loss of precision.

E.2.3.8.1. PL/pgSQL Server-Side Language

- Add ability to retrieve the current PL/PgSQL call stack using `GET DIAGNOSTICS` (Pavel Stehule, Stephen Frost)
- Add option `print_strict_params` to display the parameters passed to a query that violated a `STRICT` constraint (Marko Tiikkaja)
- Add variables `plpgsql.extra_warnings` and `plpgsql.extra_errors` to enable additional PL/pgSQL warnings and errors (Marko Tiikkaja, Petr Jelinek)

  Currently only warnings/errors about shadowed variables are available.

E.2.3.9. libpq

- Make libpq's `PQconndefaults()` function ignore invalid service files (Steve Singer, Bruce Momjian)

  Previously it returned NULL if an incorrect service file was encountered.
- Accept TLS protocol versions beyond `TLSv1` in libpq (Marko Kreen)

E.2.3.10. Client Applications

- Add createuser option `-g` to specify role membership (Chistopher Browne)
- Add vacuumdb option `--analyze-in-stages` to analyze in stages of increasing granularity (Peter Eisentraut)

  This allows minimal statistics to be created quickly.
- Make pg_resetxlog with option `-n` output current and potentially changed values (Rajeev Rastogi)
- Make initdb throw error for incorrect locale settings, rather than silently falling back to a default choice (Tom Lane)
- Make pg_ctl return exit code `4` for an inaccessible data directory (Amit Kapila, Bruce Momjian)

  This behavior more closely matches the Linux Standard Base (LSB) Core Specification.
- On Windows, ensure that a non-absolute `-D` path specification is interpreted relative to pg_ctl's current directory (Kumar Rajeev Rastogi)

  Previously it would be interpreted relative to whichever directory the underlying Windows service was started in.
- Allow `sizeof()` in ECPG C array definitions (Michael Meskes)
- Make ECPG properly handle nesting of C-style comments in both C and SQL text (Michael Meskes)

E.2.3.10.1. psql

- Suppress "No rows" output in psql `expanded` mode when the footer is disabled (Bruce Momjian)
- Allow Control-C to abort psql when it's hung at connection startup (Peter Eisentraut)

E.2.3.10.1.1. Backslash Commands

- Make psql's `\db+` show tablespace options (Magnus Hagander)
- Make `\do+` display the functions that implement the operators (Marko Tiikkaja)
- Make `\d+` output an `OID` line only if an `oid` column exists in the table (Bruce Momjian)

  Previously, the presence or absence of an `oid` column was always reported.
- Make `\d` show disabled system triggers (Bruce Momjian)

  Previously, if you disabled all triggers, only user triggers would show as disabled.
- Fix `\copy` to no longer require a space between `stdin` and a semicolon (Etsuro Fujita)
- Output the row count at the end of `\copy`, just like `COPY` already did (Kumar Rajeev Rastogi)
- Fix `\conninfo` to display the server's IP address for connections using `hostaddr` (Fujii Masao)

  Previously `\conninfo` could not display the server's IP address in such cases.
- Show the SSL protocol version in `\conninfo` (Marko Kreen)
- Add tab completion for `\pset` (Pavel Stehule)
- Allow `\pset` with no arguments to show all settings (Gilles Darold)
- Make `\s` display the name of the history file it wrote without converting it to an absolute path (Tom Lane)

  The code previously attempted to convert a relative file name to an absolute path for display, but frequently got it wrong.

E.2.3.10.2. pg_dump

- Allow pg_restore options `-I`, `-P`, `-T` and `-n` to be specified multiple times (Heikki Linnakangas)

  This allows multiple objects to be restored in one operation.
- Optionally add `IF EXISTS` clauses to the `DROP` commands emitted when removing old objects during a restore (Pavel Stehule)

  This change prevents unnecessary errors when removing old objects. The new `--if-exists` option for pg_dump, pg_dumpall, and pg_restore is only available when `--clean` is also specified.

E.2.3.10.3. pg_basebackup

- Add pg_basebackup option `--xlogdir` to specify the `pg_xlog` directory location (Haribabu Kommi)
- Allow pg_basebackup to relocate tablespaces in the backup copy (Steeve Lennmark)

  This is particularly useful for using pg_basebackup on the same machine as the primary.

- Allow network-stream base backups to be throttled (Antonin Houska)

  This can be controlled with the pg_basebackup `--max-rate` parameter.

E.2.3.11. Source Code

- Improve the way tuples are frozen to preserve forensic information (Robert Haas, Andres Freund)

  This change removes the main objection to freezing tuples as soon as possible. Code that inspects tuple flag bits will need to be modified.

- No longer require function prototypes for functions marked with the `PG_FUNCTION_INFO_V1` macro (Peter Eisentraut)

  This change eliminates the need to write boilerplate prototypes. Note that the `PG_FUNCTION_INFO_V1` macro must appear before the corresponding function definition to avoid compiler warnings.

- Remove `SnapshotNow` and `HeapTupleSatisfiesNow()` (Robert Haas)

  All existing uses have been switched to more appropriate snapshot types. Catalog scans now use MVCC snapshots.

- Add an API to allow memory allocations over one gigabyte (Noah Misch)

- Add `psprintf()` to simplify memory allocation during string composition (Peter Eisentraut, Tom Lane)

- Support `printf()` size modifier `z` to print `size_t` values (Andres Freund)

- Change API of `appendStringInfoVA()` to better use `vsnprintf()` (David Rowley, Tom Lane)

- Allow new types of external toast datums to be created (Andres Freund)

- Add single-reader, single-writer, lightweight shared message queue (Robert Haas)

- Improve spinlock speed on x86_64 CPUs (Heikki Linnakangas)

- Remove spinlock support for unsupported platforms SINIX, Sun3, and NS32K (Robert Haas)

- Remove IRIX port (Robert Haas)

- Reduce the number of semaphores required by `--disable-spinlocks` builds (Robert Haas)

- Rewrite duplicate_oids Unix shell script in Perl (Andrew Dunstan)

- Add Test Anything Protocol (TAP) tests for client programs (Peter Eisentraut)

  Currently, these tests are run by `make check-world` only if the `--enable-tap-tests` option was given to configure. This might become the default behavior in some future release.

- Add make targets `check-tests` and `installcheck-tests`, which allow selection of individual tests to be run (Andrew Dunstan)

- Remove `maintainer-check` makefile rule (Peter Eisentraut)

  The default build rules now include all the formerly-optional tests.

- Improve support for `VPATH` builds of PGXS modules (Cédric Villemain, Andrew Dunstan, Peter Eisentraut)

- Upgrade to Autoconf 2.69 (Peter Eisentraut)

- Add a configure flag that appends custom text to the `PG_VERSION` string (Oskari Saarenmaa)

This is useful for packagers building custom binaries.

- Improve DocBook XML validity (Peter Eisentraut)
- Fix various minor security and sanity issues reported by the Coverity scanner (Stephen Frost)
- Improve detection of invalid memory usage when testing PostgreSQL with Valgrind (Noah Misch)
- Improve sample Emacs configuration file `emacs.samples` (Peter Eisentraut)

  Also add `.dir-locals.el` to the top of the source tree.
- Allow pgindent to accept a command-line list of typedefs (Bruce Momjian)
- Make pgindent smarter about blank lines around preprocessor conditionals (Bruce Momjian)
- Avoid most uses of `dlltool` in Cygwin and Mingw builds (Marco Atzeri, Hiroshi Inoue)
- Support client-only installs in MSVC (Windows) builds (MauMau)

E.2.3.12. Additional Modules

- Add pg_prewarm extension to preload relation data into the shared buffer cache at server start (Robert Haas)

  This allows reaching full operating performance more quickly.
- Add UUID random number generator `gen_random_uuid()` to pgcrypto (Oskari Saarenmaa)

  This allows creation of version 4 UUIDs without requiring installation of uuid-ossp.
- Allow uuid-ossp to work with the BSD or e2fsprogs UUID libraries, not only the OSSP UUID library (Matteo Beccati)

  This improves the uuid-ossp module's portability since it no longer has to have the increasingly-obsolete OSSP library. The module's name is now rather a misnomer, but we won't change it.
- Add option to auto_explain to include trigger execution time (Horiguchi Kyotaro)
- Fix pgstattuple to not report rows from uncommitted transactions as dead (Robert Haas)
- Make pgstattuple functions use `regclass`-type arguments (Satoshi Nagayasu)

  While `text`-type arguments are still supported, they may be removed in a future major release.
- Improve consistency of pgrowlocks output to honor snapshot rules more consistently (Robert Haas)
- Improve pg_trgm's choice of trigrams for indexed regular expression searches (Alexander Korotkov)

  This change discourages use of trigrams containing whitespace, which are usually less selective.
- Allow pg_xlogdump to report a live log stream with `--follow` (Heikki Linnakangas)
- Store cube data more compactly (Stas Kelvich)

  Existing data must be dumped/restored to use the new format. The old format can still be read.
- Reduce vacuumlo client-side memory usage by using a cursor (Andrew Dunstan)
- Dramatically reduce memory consumption in pg_upgrade (Bruce Momjian)
- Pass pg_upgrade's user name (`-U`) option to generated analyze scripts (Bruce Momjian)

E.2.3.12.1. pgbench

- Remove line length limit for pgbench scripts (Sawada Masahiko)

  The previous line limit was `BUFSIZ`.
- Add long option names to pgbench (Fabien Coelho)
- Add pgbench option `--rate` to control the transaction rate (Fabien Coelho)
- Add pgbench option `--progress` to print periodic progress reports (Fabien Coelho)

E.2.3.12.2. pg_stat_statements

- Make pg_stat_statements use a file, rather than shared memory, for query text storage (Peter Geoghegan)

  This removes the previous limitation on query text length, and allows a higher number of unique statements to be tracked by default.
- Allow reporting of pg_stat_statements's internal query hash identifier (Daniel Farina, Sameer Thakur, Peter Geoghegan)
- Add the ability to retrieve all pg_stat_statements information except the query text (Peter Geoghegan)

  This allows monitoring tools to fetch query text only for just-created entries, improving performance during repeated querying of the statistics.
- Make pg_stat_statements ignore `DEALLOCATE` commands (Fabien Coelho)

  It already ignored `PREPARE`, as well as planning time in general, so this seems more consistent.
- Save the statistics file into `$PGDATA/pg_stat` at server shutdown, rather than `$PGDATA/global` (Fujii Masao)

E.3. Release 9.3.6

Release Date: 2015-02-05

This release contains a variety of fixes from 9.3.5. For information about new features in the 9.3 major release, see Section E.9.

E.3.1. Migration to Version 9.3.6

A dump/restore is not required for those running 9.3.X.

However, if you are a Windows user and are using the "Norwegian (Bokmål)" locale, manual action is needed after the upgrade to replace any "Norwegian (Bokmål)_Norway" locale names stored in PostgreSQL system catalogs with the plain-ASCII alias "Norwegian_Norway". For details see http://wiki.postgresql.org/wiki/Changes_To_Norwegian_Locale

Also, if you are upgrading from a version earlier than 9.3.5, see Section E.4.

E.3.2. Changes

- Fix buffer overruns in `to_char()` (Bruce Momjian)

  When `to_char()` processes a numeric formatting template calling for a large number of digits, PostgreSQL would read past the end of a buffer. When processing a crafted timestamp formatting template, PostgreSQL would write past the end of a buffer. Either case could crash the server. We have not ruled out the possibility of attacks that lead to privilege escalation, though they seem unlikely. (CVE-2015-0241)

- Fix buffer overrun in replacement `*printf()` functions (Tom Lane)

  PostgreSQL includes a replacement implementation of `printf` and related functions. This code will overrun a stack buffer when formatting a floating point number (conversion specifiers `e`, `E`, `f`, `F`, `g` or `G`) with requested precision greater than about 500. This will crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. A database user can trigger such a buffer overrun through the `to_char()` SQL function. While that is the only affected core PostgreSQL functionality, extension modules that use printf-family functions may be at risk as well.

  This issue primarily affects PostgreSQL on Windows. PostgreSQL uses the system implementation of these functions where adequate, which it is on other modern platforms. (CVE-2015-0242)

- Fix buffer overruns in `contrib/pgcrypto` (Marko Tiikkaja, Noah Misch)

  Errors in memory size tracking within the `pgcrypto` module permitted stack buffer overruns and improper dependence on the contents of uninitialized memory. The buffer overrun cases can crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. (CVE-2015-0243)

- Fix possible loss of frontend/backend protocol synchronization after an error (Heikki Linnakangas)

  If any error occurred while the server was in the middle of reading a protocol message from the client, it could lose synchronization and incorrectly try to interpret part of the message's data as a new protocol message. An attacker able to submit crafted binary data within a command parameter might succeed in injecting his own SQL commands this way. Statement timeout and query cancellation are the most likely sources of errors triggering this scenario. Particularly vulnerable are applications that use a timeout and also submit arbitrary user-crafted data as binary query parameters. Disabling statement timeout will reduce, but not eliminate, the risk of exploit. Our thanks to Emil Lenngren for reporting this issue. (CVE-2015-0244)

- Fix information leak via constraint-violation error messages (Stephen Frost)

  Some server error messages show the values of columns that violate a constraint, such as a unique constraint. If the user does not have `SELECT` privilege on all columns of the table, this could mean exposing values that the user should not be able to see. Adjust the code so that values are displayed only when they came from the SQL command or could be selected by the user. (CVE-2014-8161)

- Lock down regression testing's temporary installations on Windows (Noah Misch)

  Use SSPI authentication to allow connections only from the OS user who launched the test suite. This closes on Windows the same vulnerability previously closed on other platforms, namely that other users might be able to connect to the test postmaster. (CVE-2014-0067)

- Cope with the Windows locale named "Norwegian (Bokmål)" (Heikki Linnakangas)

Non-ASCII locale names are problematic since it's not clear what encoding they should be represented in. Map the troublesome locale name to a plain-ASCII alias, "Norwegian_Norway".

- Avoid possible data corruption if `ALTER DATABASE SET TABLESPACE` is used to move a database to a new tablespace and then shortly later move it back to its original tablespace (Tom Lane)
- Avoid corrupting tables when `ANALYZE` inside a transaction is rolled back (Andres Freund, Tom Lane, Michael Paquier)

  If the failing transaction had earlier removed the last index, rule, or trigger from the table, the table would be left in a corrupted state with the relevant `pg_class` flags not set though they should be.
- Ensure that unlogged tables are copied correctly during `CREATE DATABASE` or `ALTER DATABASE SET TABLESPACE` (Pavan Deolasee, Andres Freund)
- Fix incorrect processing of `CreateEventTrigStmt.eventname` (Petr Jelinek)

  This could result in misbehavior if `CREATE EVENT TRIGGER` were executed as a prepared query, or via extended query protocol.
- Fix `DROP`'s dependency searching to correctly handle the case where a table column is recursively visited before its table (Petr Jelinek, Tom Lane)

  This case is only known to arise when an extension creates both a datatype and a table using that datatype. The faulty code might refuse a `DROP EXTENSION` unless `CASCADE` is specified, which should not be required.
- Fix use-of-already-freed-memory problem in EvalPlanQual processing (Tom Lane)

  In `READ COMMITTED` mode, queries that lock or update recently-updated rows could crash as a result of this bug.
- Avoid possible deadlock while trying to acquire tuple locks in EvalPlanQual processing (Álvaro Herrera, Mark Kirkwood)
- Fix failure to wait when a transaction tries to acquire a `FOR NO KEY EXCLUSIVE` tuple lock, while multiple other transactions currently hold `FOR SHARE` locks (Álvaro Herrera)
- Fix planning of `SELECT FOR UPDATE` when using a partial index on a child table (Kyotaro Horiguchi)

  In `READ COMMITTED` mode, `SELECT FOR UPDATE` must also recheck the partial index's `WHERE` condition when rechecking a recently-updated row to see if it still satisfies the query's `WHERE` condition. This requirement was missed if the index belonged to an inheritance child table, so that it was possible to incorrectly return rows that no longer satisfy the query condition.
- Fix corner case wherein `SELECT FOR UPDATE` could return a row twice, and possibly miss returning other rows (Tom Lane)

  In `READ COMMITTED` mode, a `SELECT FOR UPDATE` that is scanning an inheritance tree could incorrectly return a row from a prior child table instead of the one it should return from a later child table.
- Improve performance of `EXPLAIN` with large range tables (Tom Lane)
- Reject duplicate column names in the referenced-columns list of a `FOREIGN KEY` declaration (David Rowley)

  This restriction is per SQL standard. Previously we did not reject the case explicitly, but later on the code would fail with bizarre-looking errors.
- Re-enable error for `SELECT ... OFFSET -1` (Tom Lane)

A negative offset value has been an error since 8.4, but an optimization added in 9.3 accidentally turned the case into a no-op. Restore the expected behavior.

- Restore previous behavior of conversion of domains to JSON (Tom Lane)

  This change causes domains over numeric and boolean to be treated like their base types for purposes of conversion to JSON. It worked like that before 9.3.5 and 9.2.9, but was unintentionally changed while fixing a related problem.

- Fix `json_agg()` to not return extra trailing right brackets in its result (Tom Lane)

- Fix bugs in raising a `numeric` value to a large integral power (Tom Lane)

  The previous code could get a wrong answer, or consume excessive amounts of time and memory before realizing that the answer must overflow.

- In `numeric_recv()`, truncate away any fractional digits that would be hidden according to the value's `dscale` field (Tom Lane)

  A `numeric` value's display scale (`dscale`) should never be less than the number of nonzero fractional digits; but apparently there's at least one broken client application that transmits binary `numeric` values in which that's true. This leads to strange behavior since the extra digits are taken into account by arithmetic operations even though they aren't printed. The least risky fix seems to be to truncate away such "hidden" digits on receipt, so that the value is indeed what it prints as.

- Fix incorrect search for shortest-first regular expression matches (Tom Lane)

  Matching would often fail when the number of allowed iterations is limited by a `?` quantifier or a bound expression.

- Reject out-of-range numeric timezone specifications (Tom Lane)

  Simple numeric timezone specifications exceeding +/- 168 hours (one week) would be accepted, but could then cause null-pointer dereference crashes in certain operations. There's no use-case for such large UTC offsets, so reject them.

- Fix bugs in `tsquery @> tsquery` operator (Heikki Linnakangas)

  Two different terms would be considered to match if they had the same CRC. Also, if the second operand had more terms than the first, it would be assumed not to be contained in the first; which is wrong since it might contain duplicate terms.

- Improve ispell dictionary's defenses against bad affix files (Tom Lane)

- Allow more than 64K phrases in a thesaurus dictionary (David Boutin)

  The previous coding could crash on an oversize dictionary, so this was deemed a back-patchable bug fix rather than a feature addition.

- Fix namespace handling in `xpath()` (Ali Akbar)

  Previously, the `xml` value resulting from an `xpath()` call would not have namespace declarations if the namespace declarations were attached to an ancestor element in the input `xml` value, rather than to the specific element being returned. Propagate the ancestral declaration so that the result is correct when considered in isolation.

- Ensure that whole-row variables expose nonempty column names to functions that pay attention to column names within composite arguments (Tom Lane)

  In some contexts, constructs like `row_to_json(tab.*)` may not produce the expected column names. This is fixed properly as of 9.4; in older branches, just ensure that we produce some nonempty name. (In some cases this will be the underlying table's column name rather than the query-assigned alias that should theoretically be visible.)

- Fix mishandling of system columns, particularly `tableoid`, in FDW queries (Etsuro Fujita)
- Fix assorted oversights in range-operator selectivity estimation (Emre Hasegeli)

  This patch fixes corner-case "unexpected operator NNNN" planner errors, and improves the selectivity estimates for some other cases.
- Avoid doing *`indexed_column`* `= ANY (`*`array`*`)` as an index qualifier if that leads to an inferior plan (Andrew Gierth)

  In some cases, `= ANY` conditions applied to non-first index columns would be done as index conditions even though it would be better to use them as simple filter conditions.
- Fix "variable not found in subplan target list" planner failure when an inline-able SQL function taking a composite argument is used in a `LATERAL` subselect and the composite argument is a lateral reference (Tom Lane)
- Fix planner problems with nested append relations, such as inherited tables within `UNION ALL` subqueries (Tom Lane)
- Fail cleanly when a GiST index tuple doesn't fit on a page, rather than going into infinite recursion (Andrew Gierth)
- Exempt tables that have per-table `cost_limit` and/or `cost_delay` settings from autovacuum's global cost balancing rules (Álvaro Herrera)

  The previous behavior resulted in basically ignoring these per-table settings, which was unintended. Now, a table having such settings will be vacuumed using those settings, independently of what is going on in other autovacuum workers. This may result in heavier total I/O load than before, so such settings should be re-examined for sanity.
- Avoid wholesale autovacuuming when autovacuum is nominally off (Tom Lane)

  Even when autovacuum is nominally off, we will still launch autovacuum worker processes to vacuum tables that are at risk of XID wraparound. However, such a worker process then proceeded to vacuum all tables in the target database, if they met the usual thresholds for autovacuuming. This is at best pretty unexpected; at worst it delays response to the wraparound threat. Fix it so that if autovacuum is turned off, workers *only* do anti-wraparound vacuums and not any other work.
- During crash recovery, ensure that unlogged relations are rewritten as empty and are synced to disk before recovery is considered complete (Abhijit Menon-Sen, Andres Freund)

  This prevents scenarios in which unlogged relations might contain garbage data following database crash recovery.
- Fix race condition between hot standby queries and replaying a full-page image (Heikki Linnakangas)

  This mistake could result in transient errors in queries being executed in hot standby.
- Fix several cases where recovery logic improperly ignored WAL records for `COMMIT/ABORT PREPARED` (Heikki Linnakangas)

  The most notable oversight was that `recovery_min_apply_delay` failed to delay application of a two-phase commit.
- Prevent latest WAL file from being archived a second time at completion of crash recovery (Fujii Masao)
- Avoid creating unnecessary `.ready` marker files for timeline history files (Fujii Masao)
- Fix possible null pointer dereference when an empty prepared statement is used and the `log_statement` setting is `mod` or `ddl` (Fujii Masao)

- Change "pgstat wait timeout" warning message to be LOG level, and rephrase it to be more understandable (Tom Lane)

  This message was originally thought to be essentially a can't-happen case, but it occurs often enough on our slower buildfarm members to be a nuisance. Reduce it to LOG level, and expend a bit more effort on the wording: it now reads "using stale statistics instead of current ones because stats collector is not responding".

- Fix possible corruption of postmaster's list of dynamic background workers (Andres Freund)

- Fix SPARC spinlock implementation to ensure correctness if the CPU is being run in a non-TSO coherency mode, as some non-Solaris kernels do (Andres Freund)

- Warn if OS X's `setlocale()` starts an unwanted extra thread inside the postmaster (Noah Misch)

- Fix processing of repeated `dbname` parameters in `PQconnectdbParams()` (Alex Shulgin)

  Unexpected behavior ensued if the first occurrence of `dbname` contained a connection string or URI to be expanded.

- Ensure that libpq reports a suitable error message on unexpected socket EOF (Marko Tiikkaja, Tom Lane)

  Depending on kernel behavior, libpq might return an empty error string rather than something useful when the server unexpectedly closed the socket.

- Clear any old error message during `PQreset()` (Heikki Linnakangas)

  If `PQreset()` is called repeatedly, and the connection cannot be re-established, error messages from the failed connection attempts kept accumulating in the `PGconn`'s error string.

- Properly handle out-of-memory conditions while parsing connection options in libpq (Alex Shulgin, Heikki Linnakangas)

- Fix array overrun in ecpg's version of `ParseDateTime()` (Michael Paquier)

- In initdb, give a clearer error message if a password file is specified but is empty (Mats Erik Andersson)

- Fix psql's `\s` command to work nicely with libedit, and add pager support (Stepan Rutz, Tom Lane)

  When using libedit rather than readline, `\s` printed the command history in a fairly unreadable encoded format, and on recent libedit versions might fail altogether. Fix that by printing the history ourselves rather than having the library do it. A pleasant side-effect is that the pager is used if appropriate.

  This patch also fixes a bug that caused newline encoding to be applied inconsistently when saving the command history with libedit. Multiline history entries written by older psql versions will be read cleanly with this patch, but perhaps not vice versa, depending on the exact libedit versions involved.

- Improve consistency of parsing of psql's special variables (Tom Lane)

  Allow variant spellings of `on` and `off` (such as `1`/`0`) for `ECHO_HIDDEN` and `ON_ERROR_ROLLBACK`. Report a warning for unrecognized values for `COMP_KEYWORD_CASE`, `ECHO`, `ECHO_HIDDEN`, `HISTCONTROL`, `ON_ERROR_ROLLBACK`, and `VERBOSITY`. Recognize all values for all these variables case-insensitively; previously there was a mishmash of case-sensitive and case-insensitive behaviors.

- Make psql's `\watch` command display nulls as specified by `\pset null` (Fujii Masao)

- Fix psql's expanded-mode display to work consistently when using `border` = 3 and `linestyle` = `ascii` or `unicode` (Stephen Frost)

- Fix pg_dump to handle comments on event triggers without failing (Tom Lane)
- Allow parallel pg_dump to use `--serializable-deferrable` (Kevin Grittner)
- Improve performance of pg_dump when the database contains many instances of multiple dependency paths between the same two objects (Tom Lane)
- Fix pg_dumpall to restore its ability to dump from pre-8.1 servers (Gilles Darold)
- Fix possible deadlock during parallel restore of a schema-only dump (Robert Haas, Tom Lane)
- Fix core dump in `pg_dump --binary-upgrade` on zero-column composite type (Rushabh Lathia)
- Fix failure to fsync tables in nondefault tablespaces during pg_upgrade (Abhijit Menon-Sen, Andres Freund)

  With an operating system crash and some bad luck, this could result in data loss during an upgrade.
- In pg_upgrade, cope with cases where the new cluster creates a TOAST table for a table that didn't previously have one (Bruce Momjian)

  Previously this could result in failures due to OID conflicts.
- In pg_upgrade, don't try to set `autovacuum_multixact_freeze_max_age` for the old cluster (Bruce Momjian)

  This could result in failure because not all 9.3.X versions have that parameter. Fortunately, we don't actually need to set it at all.
- In pg_upgrade, preserve the transaction ID epoch (Bruce Momjian)

  This oversight did not bother PostgreSQL proper, but could confuse some external replication tools.
- Prevent WAL files created by `pg_basebackup -x/-X` from being archived again when the standby is promoted (Andres Freund)
- Fix memory leak in pg_receivexlog (Fujii Masao)
- Fix unintended suppression of pg_receivexlog verbose messages (Fujii Masao)
- Fix failure of `contrib/auto_explain` to print per-node timing information when doing `EXPLAIN ANALYZE` (Tom Lane)
- Fix upgrade-from-unpackaged script for `contrib/citext` (Tom Lane)
- Avoid integer overflow and buffer overrun in `contrib/hstore`'s `hstore_to_json()` (Heikki Linnakangas)
- Fix recognition of numbers in `hstore_to_json_loose()`, so that JSON numbers and strings are correctly distinguished (Andrew Dunstan)
- Fix block number checking in `contrib/pageinspect`'s `get_raw_page()` (Tom Lane)

  The incorrect checking logic could prevent access to some pages in non-main relation forks.
- Fix `contrib/pgcrypto`'s `pgp_sym_decrypt()` to not fail on messages whose length is 6 less than a power of 2 (Marko Tiikkaja)
- Fix file descriptor leak in `contrib/pg_test_fsync` (Jeff Janes)

  This could cause failure to remove temporary files on Windows.
- Handle unexpected query results, especially NULLs, safely in `contrib/tablefunc`'s `connectby()` (Michael Paquier)

  `connectby()` previously crashed if it encountered a NULL key value. It now prints that row but doesn't recurse further.

- Avoid a possible crash in `contrib/xml2`'s `xslt_process()` (Mark Simonetti)

  libxslt seems to have an undocumented dependency on the order in which resources are freed; reorder our calls to avoid a crash.

- Mark some `contrib` I/O functions with correct volatility properties (Tom Lane)

  The previous over-conservative marking was immaterial in normal use, but could cause optimization problems or rejection of valid index expression definitions. Since the consequences are not large, we've just adjusted the function definitions in the extension modules' scripts, without changing version numbers.

- Numerous cleanups of warnings from Coverity static code analyzer (Andres Freund, Tatsuo Ishii, Marko Kreen, Tom Lane, Michael Paquier)

  These changes are mostly cosmetic but in some cases fix corner-case bugs, for example a crash rather than a proper error report after an out-of-memory failure. None are believed to represent security issues.

- Fix setup of background workers in EXEC_BACKEND builds, eg Windows (Robert Haas)

- Detect incompatible OpenLDAP versions during build (Noah Misch)

  With OpenLDAP versions 2.4.24 through 2.4.31, inclusive, PostgreSQL backends can crash at exit. Raise a warning during configure based on the compile-time OpenLDAP version number, and test the crashing scenario in the `contrib/dblink` regression test.

- In non-MSVC Windows builds, ensure `libpq.dll` is installed with execute permissions (Noah Misch)

- Make pg_regress remove any temporary installation it created upon successful exit (Tom Lane)

  This results in a very substantial reduction in disk space usage during `make check-world`, since that sequence involves creation of numerous temporary installations.

- Support time zone abbreviations that change UTC offset from time to time (Tom Lane)

  Previously, PostgreSQL assumed that the UTC offset associated with a time zone abbreviation (such as `EST`) never changes in the usage of any particular locale. However this assumption fails in the real world, so introduce the ability for a zone abbreviation to represent a UTC offset that sometimes changes. Update the zone abbreviation definition files to make use of this feature in timezone locales that have changed the UTC offset of their abbreviations since 1970 (according to the IANA timezone database). In such timezones, PostgreSQL will now associate the correct UTC offset with the abbreviation depending on the given date.

- Update time zone abbreviations lists (Tom Lane)

  Add CST (China Standard Time) to our lists. Remove references to ADT as "Arabia Daylight Time", an abbreviation that's been out of use since 2007; therefore, claiming there is a conflict with "Atlantic Daylight Time" doesn't seem especially helpful. Fix entirely incorrect GMT offsets for CKT (Cook Islands), FJT, and FJST (Fiji); we didn't even have them on the proper side of the date line.

- Update time zone data files to tzdata release 2015a.

  The IANA timezone database has adopted abbreviations of the form `AxST`/`AxDT` for all Australian time zones, reflecting what they believe to be current majority practice Down Under. These names do not conflict with usage elsewhere (other than ACST for Acre Summer Time, which has been in disuse since 1994). Accordingly, adopt these names into our "Default" timezone abbreviation set. The "Australia" abbreviation set now contains only CST, EAST, EST, SAST, SAT, and WST, all of which are thought to be mostly historical usage. Note that SAST has also been changed to be South Africa Standard Time in the "Default" abbreviation set.

Also, add zone abbreviations SRET (Asia/Srednekolymsk) and XJT (Asia/Urumqi), and use WSST/WSDT for western Samoa. Also, there were DST law changes in Chile, Mexico, the Turks & Caicos Islands (America/Grand_Turk), and Fiji. There is a new zone Pacific/Bougainville for portions of Papua New Guinea. Also, numerous corrections for historical (pre-1970) time zone data.

E.4. Release 9.3.5

Release Date: 2014-07-24

This release contains a variety of fixes from 9.3.4. For information about new features in the 9.3 major release, see Section E.9.

E.4.1. Migration to Version 9.3.5

A dump/restore is not required for those running 9.3.X.

However, this release corrects a logic error in pg_upgrade, as well as an index corruption problem in some GiST indexes. See the first two changelog entries below to find out whether your installation has been affected and what steps you should take if so.

Also, if you are upgrading from a version earlier than 9.3.4, see Section E.5.

E.4.2. Changes

- In pg_upgrade, remove `pg_multixact` files left behind by initdb (Bruce Momjian)

  If you used a pre-9.3.5 version of pg_upgrade to upgrade a database cluster to 9.3, it might have left behind a file `$PGDATA/pg_multixact/offsets/0000` that should not be there and will eventually cause problems in `VACUUM`. *However, in common cases this file is actually valid and must not be removed.* To determine whether your installation has this problem, run this query as superuser, in any database of the cluster:

  ```
  WITH list(file) AS (SELECT * FROM pg_ls_dir('pg_multixact/offsets'))
  SELECT EXISTS (SELECT * FROM list WHERE file = '0000') AND
         NOT EXISTS (SELECT * FROM list WHERE file = '0001') AND
         NOT EXISTS (SELECT * FROM list WHERE file = 'FFFF') AND
         EXISTS (SELECT * FROM list WHERE file != '0000')
         AS file_0000_removal_required;
  ```

  If this query returns `t`, manually remove the file `$PGDATA/pg_multixact/offsets/0000`. Do nothing if the query returns `f`.

- Correctly initialize padding bytes in `contrib/btree_gist` indexes on `bit` columns (Heikki Linnakangas)

  This error could result in incorrect query results due to values that should compare equal not being seen as equal. Users with GiST indexes on `bit` or `bit varying` columns should `REINDEX` those indexes after installing this update.

- Protect against torn pages when deleting GIN list pages (Heikki Linnakangas)

This fix prevents possible index corruption if a system crash occurs while the page update is being written to disk.

- Don't clear the right-link of a GiST index page while replaying updates from WAL (Heikki Linnakangas)

  This error could lead to transiently wrong answers from GiST index scans performed in Hot Standby.

- Fix corner-case infinite loop during insertion into an SP-GiST text index (Tom Lane)

- Fix incorrect answers from SP-GiST index searches with `-|-` (range adjacency) operator (Heikki Linnakangas)

- Fix wraparound handling for `pg_multixact/members` (Álvaro Herrera)

- Truncate `pg_multixact` during checkpoints, not during `VACUUM` (Álvaro Herrera)

  This change ensures that `pg_multixact` segments can't be removed if they'd still be needed during WAL replay after a crash.

- Fix possible inconsistency of all-visible flags after WAL recovery (Heikki Linnakangas)

- Fix possibly-incorrect cache invalidation during nested calls to `ReceiveSharedInvalidMessages` (Andres Freund)

- Fix race condition when updating a tuple concurrently locked by another process (Andres Freund, Álvaro Herrera)

- Fix "could not find pathkey item to sort" planner failures with `UNION ALL` over subqueries reading from tables with inheritance children (Tom Lane)

- Don't assume a subquery's output is unique if there's a set-returning function in its targetlist (David Rowley)

  This oversight could lead to misoptimization of constructs like `WHERE x IN (SELECT y, generate_series(1,10) FROM t GROUP BY y)`.

- Improve planner to drop constant-NULL inputs of `AND`/`OR` when possible (Tom Lane)

  This change fixes some cases where the more aggressive parameter substitution done by 9.2 and later can lead to a worse plan than older versions produced.

- Ensure that the planner sees equivalent `VARIADIC` and non-`VARIADIC` function calls as equivalent (Tom Lane)

  This bug could for example result in failure to use expression indexes involving variadic functions. It might be necessary to re-create such indexes, and/or re-create views including variadic function calls that should match the indexes, for the fix to be effective for existing 9.3 installations.

- Fix handling of nested `JSON` objects in `json_populate_recordset()` and friends (Michael Paquier, Tom Lane)

  A nested `JSON` object could result in previous fields of the parent object not being shown in the output.

- Fix identification of input type category in `to_json()` and friends (Tom Lane)

  This is known to have led to inadequate quoting of `money` fields in the `JSON` result, and there may have been wrong results for other data types as well.

- Fix failure to detoast fields in composite elements of structured types (Tom Lane)

  This corrects cases where TOAST pointers could be copied into other tables without being dereferenced. If the original data is later deleted, it would lead to errors like "missing chunk number 0 for toast value ..." when the now-dangling pointer is used.

- Fix "record type has not been registered" failures with whole-row references to the output of Append plan nodes (Tom Lane)
- Fix possible crash when invoking a user-defined function while rewinding a cursor (Tom Lane)
- Fix query-lifespan memory leak while evaluating the arguments for a function in `FROM` (Tom Lane)
- Fix session-lifespan memory leaks in regular-expression processing (Tom Lane, Arthur O'Dwyer, Greg Stark)
- Fix data encoding error in `hungarian.stop` (Tom Lane)
- Prevent foreign tables from being created with OIDS when default_with_oids is true (Etsuro Fujita)
- Fix liveness checks for rows that were inserted in the current transaction and then deleted by a now-rolled-back subtransaction (Andres Freund)

  This could cause problems (at least spurious warnings, and at worst an infinite loop) if `CREATE INDEX` or `CLUSTER` were done later in the same transaction.
- Clear `pg_stat_activity.xact_start` during `PREPARE TRANSACTION` (Andres Freund)

  After the `PREPARE`, the originating session is no longer in a transaction, so it should not continue to display a transaction start time.
- Fix `REASSIGN OWNED` to not fail for text search objects (Álvaro Herrera)
- Prevent `pg_class.relminmxid` values from going backwards during `VACUUM FULL` (Álvaro Herrera)
- Reduce indentation in rule/view dumps to improve readability and avoid excessive whitespace (Greg Stark, Tom Lane)

  This change reduces the amount of indentation applied to nested constructs, including some cases that the user probably doesn't think of as nested, such as UNION lists. Previously, deeply nested constructs were printed with an amount of whitespace growing as O(N^2), which created a performance problem and even risk of out-of-memory failures. Now the indentation is reduced modulo 40, which is initially odd to look at but seems to preserve readability better than simply limiting the indentation would do. Redundant parenthesization of UNION lists has been reduced as well.
- Fix dumping of rules/views when subsequent addition of a column has resulted in multiple input columns matching a `USING` specification (Tom Lane)
- Repair view printing for some cases involving functions in `FROM` that return a composite type containing dropped columns (Tom Lane)
- Block signals during postmaster startup (Tom Lane)

  This ensures that the postmaster will properly clean up after itself if, for example, it receives SIGINT while still starting up.
- Fix client host name lookup when processing `pg_hba.conf` entries that specify host names instead of IP addresses (Tom Lane)

  Ensure that reverse-DNS lookup failures are reported, instead of just silently not matching such entries. Also ensure that we make only one reverse-DNS lookup attempt per connection, not one per host name entry, which is what previously happened if the lookup attempts failed.
- Allow the root user to use `postgres -C variable` and `postgres --describe-config` (MauMau)

  The prohibition on starting the server as root does not need to extend to these operations, and relaxing it prevents failure of pg_ctl in some scenarios.
- Secure Unix-domain sockets of temporary postmasters started during `make check` (Noah Misch)

Any local user able to access the socket file could connect as the server's bootstrap superuser, then proceed to execute arbitrary code as the operating-system user running the test, as we previously noted in CVE-2014-0067. This change defends against that risk by placing the server's socket in a temporary, mode 0700 subdirectory of `/tmp`. The hazard remains however on platforms where Unix sockets are not supported, notably Windows, because then the temporary postmaster must accept local TCP connections.

A useful side effect of this change is to simplify `make check` testing in builds that override `DEFAULT_PGSOCKET_DIR`. Popular non-default values like `/var/run/postgresql` are often not writable by the build user, requiring workarounds that will no longer be necessary.

- Fix tablespace creation WAL replay to work on Windows (MauMau)
- Fix detection of socket creation failures on Windows (Bruce Momjian)
- On Windows, allow new sessions to absorb values of PGC_BACKEND parameters (such as log_connections) from the configuration file (Amit Kapila)

  Previously, if such a parameter were changed in the file post-startup, the change would have no effect.
- Properly quote executable path names on Windows (Nikhil Deshpande)

  This oversight could cause initdb and pg_upgrade to fail on Windows, if the installation path contained both spaces and `@` signs.
- Fix linking of libpython on OS X (Tom Lane)

  The method we previously used can fail with the Python library supplied by Xcode 5.0 and later.
- Avoid buffer bloat in libpq when the server consistently sends data faster than the client can absorb it (Shin-ichi Morita, Tom Lane)

  libpq could be coerced into enlarging its input buffer until it runs out of memory (which would be reported misleadingly as "lost synchronization with server"). Under ordinary circumstances it's quite far-fetched that data could be continuously transmitted more quickly than the `recv()` loop can absorb it, but this has been observed when the client is artificially slowed by scheduler constraints.
- Ensure that LDAP lookup attempts in libpq time out as intended (Laurenz Albe)
- Fix ecpg to do the right thing when an array of `char *` is the target for a FETCH statement returning more than one row, as well as some other array-handling fixes (Ashutosh Bapat)
- Fix pg_dump to cope with a materialized view that depends on a table's primary key (Tom Lane)

  This occurs if the view's query relies on functional dependency to abbreviate a `GROUP BY` list. pg_dump got sufficiently confused that it dumped the materialized view as a regular view.
- Fix parsing of pg_dumpall's `-i` switch (Tom Lane)
- Fix pg_restore's processing of old-style large object comments (Tom Lane)

  A direct-to-database restore from an archive file generated by a pre-9.0 version of pg_dump would usually fail if the archive contained more than a few comments for large objects.
- Fix pg_upgrade for cases where the new server creates a TOAST table but the old version did not (Bruce Momjian)

  This rare situation would manifest as "relation OID mismatch" errors.
- In pg_upgrade, preserve `pg_database.datminmxid` and `pg_class.relminmxid` values from the old cluster, or insert reasonable values when upgrading from pre-9.3; also defend against unreasonable values in the core server (Bruce Momjian, Álvaro Herrera, Tom Lane)

These changes prevent scenarios in which autovacuum might insist on scanning the entire cluster's contents immediately upon starting the new cluster, or in which tracking of unfrozen MXID values might be disabled completely.

- Prevent `contrib/auto_explain` from changing the output of a user's `EXPLAIN` (Tom Lane)

  If `auto_explain` is active, it could cause an `EXPLAIN (ANALYZE, TIMING OFF)` command to nonetheless print timing information.

- Fix query-lifespan memory leak in `contrib/dblink` (MauMau, Joe Conway)
- In `contrib/pgcrypto` functions, ensure sensitive information is cleared from stack variables before returning (Marko Kreen)
- Prevent use of already-freed memory in `contrib/pgstattuple`'s `pgstat_heap()` (Noah Misch)
- In `contrib/uuid-ossp`, cache the state of the OSSP UUID library across calls (Tom Lane)

  This improves the efficiency of UUID generation and reduces the amount of entropy drawn from `/dev/urandom`, on platforms that have that.

- Update time zone data files to tzdata release 2014e for DST law changes in Crimea, Egypt, and Morocco.

E.5. Release 9.3.4

Release Date: 2014-03-20

This release contains a variety of fixes from 9.3.3. For information about new features in the 9.3 major release, see Section E.9.

E.5.1. Migration to Version 9.3.4

A dump/restore is not required for those running 9.3.X.

However, the error fixed in the first changelog entry below could have resulted in corrupt data on standby servers. It may be prudent to reinitialize standby servers from fresh base backups after installing this update.

Also, if you are upgrading from a version earlier than 9.3.3, see Section E.6.

E.5.2. Changes

- Fix WAL replay of locking an already-updated tuple (Andres Freund, Álvaro Herrera)

  This error caused updated rows to not be found by index scans, resulting in inconsistent query results depending on whether an index scan was used. Subsequent processing could result in constraint violations, since the previously updated row would not be found by later index searches, thus possibly allowing conflicting rows to be inserted. Since this error is in WAL replay, it would only manifest during crash recovery or on standby servers. The improperly-replayed case most

commonly arises when a table row that is referenced by a foreign-key constraint is updated concurrently with creation of a referencing row.

- Restore GIN metapages unconditionally to avoid torn-page risk (Heikki Linnakangas)

  Although this oversight could theoretically result in a corrupted index, it is unlikely to have caused any problems in practice, since the active part of a GIN metapage is smaller than a standard 512-byte disk sector.

- Avoid race condition in checking transaction commit status during receipt of a `NOTIFY` message (Marko Tiikkaja)

  This prevents a scenario wherein a sufficiently fast client might respond to a notification before database updates made by the notifier have become visible to the recipient.

- Allow materialized views to be referenced in `UPDATE` and `DELETE` commands (Michael Paquier)

  Previously such queries failed with a complaint about not being able to lock rows in the materialized view.

- Allow regular-expression operators to be terminated early by query cancel requests (Tom Lane)

  This prevents scenarios wherein a pathological regular expression could lock up a server process uninterruptably for a long time.

- Remove incorrect code that tried to allow `OVERLAPS` with single-element row arguments (Joshua Yanovski)

  This code never worked correctly, and since the case is neither specified by the SQL standard nor documented, it seemed better to remove it than fix it.

- Avoid getting more than `AccessShareLock` when de-parsing a rule or view (Dean Rasheed)

  This oversight resulted in pg_dump unexpectedly acquiring `RowExclusiveLock` locks on tables mentioned as the targets of `INSERT`/`UPDATE`/`DELETE` commands in rules. While usually harmless, that could interfere with concurrent transactions that tried to acquire, for example, `ShareLock` on those tables.

- Improve performance of index endpoint probes during planning (Tom Lane)

  This change fixes a significant performance problem that occurred when there were many not-yet-committed rows at the end of the index, which is a common situation for indexes on sequentially-assigned values such as timestamps or sequence-generated identifiers.

- Use non-default selectivity estimates for *`value`* `IN (`*`list`*`)` and *`value operator`* `ANY (`*`array`*`)` expressions when the righthand side is a stable expression (Tom Lane)

- Remove the correct per-database statistics file during `DROP DATABASE` (Tomas Vondra)

  This fix prevents a permanent leak of statistics file space. Users who have done many `DROP DATABASE` commands since upgrading to PostgreSQL 9.3 may wish to check their statistics directory and delete statistics files that do not correspond to any existing database. Please note that `db_0.stat` should not be removed.

- Fix walsender ping logic to avoid inappropriate disconnects under continuous load (Andres Freund, Heikki Linnakangas)

  walsender failed to send ping messages to the client if it was constantly busy sending WAL data; but it expected to see ping responses despite that, and would therefore disconnect once wal_sender_timeout elapsed.

- Fix walsender's failure to shut down cleanly when client is pg_receivexlog (Fujii Masao)

- Check WAL level and hot standby parameters correctly when doing crash recovery that will be followed by archive recovery (Heikki Linnakangas)
- Fix test to see if hot standby connections can be allowed immediately after a crash (Heikki Linnakangas)
- Add read-only data_checksums parameter to display whether page checksums are enabled (Heikki Linnakangas)

  Without this parameter, determining the state of checksum processing was difficult.
- Prevent interrupts while reporting non-`ERROR` messages (Tom Lane)

  This guards against rare server-process freezeups due to recursive entry to `syslog()`, and perhaps other related problems.
- Fix memory leak in PL/Perl when returning a composite result, including multiple-OUT-parameter cases (Alex Hunsaker)
- Fix tracking of psql script line numbers during `\copy` from out-of-line data (Kumar Rajeev Rastogi, Amit Khandekar)

  `\copy ... from` incremented the script file line number for each data line, even if the data was not coming from the script file. This mistake resulted in wrong line numbers being reported for any errors occurring later in the same script file.
- Fix contrib/postgres_fdw to handle multiple join conditions properly (Tom Lane)

  This oversight could result in sending `WHERE` clauses to the remote server for execution even though the clauses are not known to have the same semantics on the remote server (for example, clauses that use non-built-in operators). The query might succeed anyway, but it could also fail with errors from the remote server, or worse give silently wrong answers.
- Prevent intermittent "could not reserve shared memory region" failures on recent Windows versions (MauMau)
- Update time zone data files to tzdata release 2014a for DST law changes in Fiji and Turkey, plus historical changes in Israel and Ukraine.

E.6. Release 9.3.3

Release Date: 2014-02-20

This release contains a variety of fixes from 9.3.2. For information about new features in the 9.3 major release, see Section E.9.

E.6.1. Migration to Version 9.3.3

A dump/restore is not required for those running 9.3.X.

However, several of the issues corrected in this release could have resulted in corruption of foreign-key constraints; that is, there might now be referencing rows for which there is no matching row in the referenced table. It may be worthwhile to recheck such constraints after installing this update. The simplest way to do that is to drop and recreate each suspect constraint; however, that will require

taking an exclusive lock on both tables, so it is unlikely to be acceptable in production databases. Alternatively, you can do a manual join query between the two tables to look for unmatched rows.

Note also the requirement for replication standby servers to be upgraded before their master server is upgraded.

Also, if you are upgrading from a version earlier than 9.3.2, see Section E.7.

E.6.2. Changes

- Shore up `GRANT ... WITH ADMIN OPTION` restrictions (Noah Misch)

  Granting a role without `ADMIN OPTION` is supposed to prevent the grantee from adding or removing members from the granted role, but this restriction was easily bypassed by doing `SET ROLE` first. The security impact is mostly that a role member can revoke the access of others, contrary to the wishes of his grantor. Unapproved role member additions are a lesser concern, since an uncooperative role member could provide most of his rights to others anyway by creating views or `SECURITY DEFINER` functions. (CVE-2014-0060)

- Prevent privilege escalation via manual calls to PL validator functions (Andres Freund)

  The primary role of PL validator functions is to be called implicitly during `CREATE FUNCTION`, but they are also normal SQL functions that a user can call explicitly. Calling a validator on a function actually written in some other language was not checked for and could be exploited for privilege-escalation purposes. The fix involves adding a call to a privilege-checking function in each validator function. Non-core procedural languages will also need to make this change to their own validator functions, if any. (CVE-2014-0061)

- Avoid multiple name lookups during table and index DDL (Robert Haas, Andres Freund)

  If the name lookups come to different conclusions due to concurrent activity, we might perform some parts of the DDL on a different table than other parts. At least in the case of `CREATE INDEX`, this can be used to cause the permissions checks to be performed against a different table than the index creation, allowing for a privilege escalation attack. (CVE-2014-0062)

- Prevent buffer overrun with long datetime strings (Noah Misch)

  The `MAXDATELEN` constant was too small for the longest possible value of type `interval`, allowing a buffer overrun in `interval_out()`. Although the datetime input functions were more careful about avoiding buffer overrun, the limit was short enough to cause them to reject some valid inputs, such as input containing a very long timezone name. The ecpg library contained these vulnerabilities along with some of its own. (CVE-2014-0063)

- Prevent buffer overrun due to integer overflow in size calculations (Noah Misch, Heikki Linnakangas)

  Several functions, mostly type input functions, calculated an allocation size without checking for overflow. If overflow did occur, a too-small buffer would be allocated and then written past. (CVE-2014-0064)

- Prevent overruns of fixed-size buffers (Peter Eisentraut, Jozef Mlich)

  Use `strlcpy()` and related functions to provide a clear guarantee that fixed-size buffers are not overrun. Unlike the preceding items, it is unclear whether these cases really represent live issues, since in most cases there appear to be previous constraints on the size of the input string. Nonetheless it seems prudent to silence all Coverity warnings of this type. (CVE-2014-0065)

- Avoid crashing if `crypt()` returns NULL (Honza Horak, Bruce Momjian)

There are relatively few scenarios in which `crypt()` could return NULL, but `contrib/chkpass` would crash if it did. One practical case in which this could be an issue is if libc is configured to refuse to execute unapproved hashing algorithms (e.g., "FIPS mode"). (CVE-2014-0066)

- Document risks of `make check` in the regression testing instructions (Noah Misch, Tom Lane)

  Since the temporary server started by `make check` uses "trust" authentication, another user on the same machine could connect to it as database superuser, and then potentially exploit the privileges of the operating-system user who started the tests. A future release will probably incorporate changes in the testing procedure to prevent this risk, but some public discussion is needed first. So for the moment, just warn people against using `make check` when there are untrusted users on the same machine. (CVE-2014-0067)

- Rework tuple freezing protocol (Álvaro Herrera, Andres Freund)

  The logic for tuple freezing was unable to handle some cases involving freezing of *multixact* IDs, with the practical effect that shared row-level locks might be forgotten once old enough.

  Fixing this required changing the WAL record format for tuple freezing. While this is no issue for standalone servers, when using replication it means that *standby servers must be upgraded to 9.3.3 or later before their masters are*. An older standby will be unable to interpret freeze records generated by a newer master, and will fail with a PANIC message. (In such a case, upgrading the standby should be sufficient to let it resume execution.)

- Create separate GUC parameters to control multixact freezing (Álvaro Herrera)

  9.3 requires multixact tuple labels to be frozen before they grow too old, in the same fashion as plain transaction ID labels have been frozen for some time. Previously, the transaction ID freezing parameters were used for multixact IDs too; but since the consumption rates of transaction IDs and multixact IDs can be quite different, this did not work very well. Introduce new settings vacuum_multixact_freeze_min_age, vacuum_multixact_freeze_table_age, and autovacuum_multixact_freeze_max_age to control when to freeze multixacts.

- Account for remote row locks propagated by local updates (Álvaro Herrera)

  If a row was locked by transaction A, and transaction B updated it, the new version of the row created by B would be locked by A, yet visible only to B. If transaction B then again updated the row, A's lock wouldn't get checked, thus possibly allowing B to complete when it shouldn't. This case is new in 9.3 since prior versions did not have any types of row locking that would permit another transaction to update the row at all.

  This oversight could allow referential integrity checks to give false positives (for instance, allow deletes that should have been rejected). Applications using the new commands `SELECT FOR KEY SHARE` and `SELECT FOR NO KEY UPDATE` might also have suffered locking failures of this kind.

- Prevent "forgetting" valid row locks when one of several holders of a row lock aborts (Álvaro Herrera)

  This was yet another mechanism by which a shared row lock could be lost, thus possibly allowing updates that should have been prevented by foreign-key constraints.

- Fix incorrect logic during update chain locking (Álvaro Herrera)

  This mistake could result in spurious "could not serialize access due to concurrent update" errors in `REPEATABLE READ` and `SERIALIZABLE` transaction isolation modes.

- Handle wraparound correctly during extension or truncation of `pg_multixact/members` (Andres Freund, Álvaro Herrera)

- Fix handling of 5-digit filenames in `pg_multixact/members` (Álvaro Herrera)

  As of 9.3, these names can be more than 4 digits, but the directory cleanup code ignored such files.

- Improve performance of multixact cache code (Álvaro Herrera)
- Optimize updating a row that's already locked by the same transaction (Andres Freund, Álvaro Herrera)

  This fixes a performance regression from pre-9.3 versions when doing `SELECT FOR UPDATE` followed by `UPDATE/DELETE`.
- During archive recovery, prefer highest timeline number when WAL segments with the same ID are present in both the archive and `pg_xlog/` (Kyotaro Horiguchi)

  Previously, not-yet-archived segments could get ignored during recovery. This reverts an undesirable behavioral change in 9.3.0 back to the way things worked pre-9.3.
- Fix possible mis-replay of WAL records when some segments of a relation aren't full size (Greg Stark, Tom Lane)

  The WAL update could be applied to the wrong page, potentially many pages past where it should have been. Aside from corrupting data, this error has been observed to result in significant "bloat" of standby servers compared to their masters, due to updates being applied far beyond where the end-of-file should have been. This failure mode does not appear to be a significant risk during crash recovery, only when initially synchronizing a standby created from a base backup taken from a quickly-changing master.
- Fix bug in determining when recovery has reached consistency (Tomonari Katsumata, Heikki Linnakangas)

  In some cases WAL replay would mistakenly conclude that the database was already consistent at the start of replay, thus possibly allowing hot-standby queries before the database was really consistent. Other symptoms such as "PANIC: WAL contains references to invalid pages" were also possible.
- Fix WAL logging of visibility map changes (Heikki Linnakangas)
- Fix improper locking of btree index pages while replaying a `VACUUM` operation in hot-standby mode (Andres Freund, Heikki Linnakangas, Tom Lane)

  This error could result in "PANIC: WAL contains references to invalid pages" failures.
- Ensure that insertions into non-leaf GIN index pages write a full-page WAL record when appropriate (Heikki Linnakangas)

  The previous coding risked index corruption in the event of a partial-page write during a system crash.
- When `pause_at_recovery_target` and `recovery_target_inclusive` are both set, ensure the target record is applied before pausing, not after (Heikki Linnakangas)
- Ensure walreceiver sends hot-standby feedback messages on time even when there is a continuous stream of data (Andres Freund, Amit Kapila)
- Prevent timeout interrupts from taking control away from mainline code unless `ImmediateInterruptOK` is set (Andres Freund, Tom Lane)

  This is a serious issue for any application making use of statement timeouts, as it could cause all manner of strange failures after a timeout occurred. We have seen reports of "stuck" spinlocks, ERRORs being unexpectedly promoted to PANICs, unkillable backends, and other misbehaviors.
- Fix race conditions during server process exit (Robert Haas)

  Ensure that signal handlers don't attempt to use the process's `MyProc` pointer after it's no longer valid.

- Fix race conditions in walsender shutdown logic and walreceiver SIGHUP signal handler (Tom Lane)
- Fix unsafe references to `errno` within error reporting logic (Christian Kruse)

  This would typically lead to odd behaviors such as missing or inappropriate `HINT` fields.
- Fix possible crashes from using `ereport()` too early during server startup (Tom Lane)

  The principal case we've seen in the field is a crash if the server is started in a directory it doesn't have permission to read.
- Clear retry flags properly in OpenSSL socket write function (Alexander Kukushkin)

  This omission could result in a server lockup after unexpected loss of an SSL-encrypted connection.
- Fix length checking for Unicode identifiers (`U&"..."` syntax) containing escapes (Tom Lane)

  A spurious truncation warning would be printed for such identifiers if the escaped form of the identifier was too long, but the identifier actually didn't need truncation after de-escaping.
- Fix parsing of Unicode literals and identifiers just before the end of a command string or function body (Tom Lane)
- Allow keywords that are type names to be used in lists of roles (Stephen Frost)

  A previous patch allowed such keywords to be used without quoting in places such as role identifiers; but it missed cases where a list of role identifiers was permitted, such as `DROP ROLE`.
- Fix parser crash for `EXISTS(SELECT * FROM zero_column_table)` (Tom Lane)
- Fix possible crash due to invalid plan for nested sub-selects, such as `WHERE (... x IN (SELECT ...) ...) IN (SELECT ...)` (Tom Lane)
- Fix mishandling of `WHERE` conditions pulled up from a `LATERAL` subquery (Tom Lane)

  The typical symptom of this bug was a "JOIN qualification cannot refer to other relations" error, though subtle logic errors in created plans seem possible as well.
- Disallow `LATERAL` references to the target table of an `UPDATE/DELETE` (Tom Lane)

  While this might be allowed in some future release, it was unintentional in 9.3, and didn't work quite right anyway.
- Fix `UPDATE/DELETE` of an inherited target table that has `UNION ALL` subqueries (Tom Lane)

  Without this fix, `UNION ALL` subqueries aren't correctly inserted into the update plans for inheritance child tables after the first one, typically resulting in no update happening for those child table(s).
- Fix `ANALYZE` to not fail on a column that's a domain over a range type (Tom Lane)
- Ensure that `ANALYZE` creates statistics for a table column even when all the values in it are "too wide" (Tom Lane)

  `ANALYZE` intentionally omits very wide values from its histogram and most-common-values calculations, but it neglected to do something sane in the case that all the sampled entries are too wide.
- In `ALTER TABLE ... SET TABLESPACE`, allow the database's default tablespace to be used without a permissions check (Stephen Frost)

  `CREATE TABLE` has always allowed such usage, but `ALTER TABLE` didn't get the memo.
- Fix support for extensions containing event triggers (Tom Lane)
- Fix "cannot accept a set" error when some arms of a `CASE` return a set and others don't (Tom Lane)

- Fix memory leakage in JSON functions (Craig Ringer)
- Properly distinguish numbers from non-numbers when generating JSON output (Andrew Dunstan)
- Fix checks for all-zero client addresses in pgstat functions (Kevin Grittner)
- Fix possible misclassification of multibyte characters by the text search parser (Tom Lane)

  Non-ASCII characters could be misclassified when using C locale with a multibyte encoding. On Cygwin, non-C locales could fail as well.
- Fix possible misbehavior in `plainto_tsquery()` (Heikki Linnakangas)

  Use `memmove()` not `memcpy()` for copying overlapping memory regions. There have been no field reports of this actually causing trouble, but it's certainly risky.
- Fix placement of permissions checks in `pg_start_backup()` and `pg_stop_backup()` (Andres Freund, Magnus Hagander)

  The previous coding might attempt to do catalog access when it shouldn't.
- Accept `SHIFT_JIS` as an encoding name for locale checking purposes (Tatsuo Ishii)
- Fix `*`-qualification of named parameters in SQL-language functions (Tom Lane)

  Given a composite-type parameter named `foo`, `$1.*` worked fine, but `foo.*` not so much.
- Fix misbehavior of `PQhost()` on Windows (Fujii Masao)

  It should return `localhost` if no host has been specified.
- Improve error handling in libpq and psql for failures during `COPY TO STDOUT/FROM STDIN` (Tom Lane)

  In particular this fixes an infinite loop that could occur in 9.2 and up if the server connection was lost during `COPY FROM STDIN`. Variants of that scenario might be possible in older versions, or with other client applications.
- Fix incorrect translation handling in some psql `\d` commands (Peter Eisentraut, Tom Lane)
- Ensure pg_basebackup's background process is killed when exiting its foreground process (Magnus Hagander)
- Fix possible incorrect printing of filenames in pg_basebackup's verbose mode (Magnus Hagander)
- Avoid including tablespaces inside PGDATA twice in base backups (Dimitri Fontaine, Magnus Hagander)
- Fix misaligned descriptors in ecpg (MauMau)
- In ecpg, handle lack of a hostname in the connection parameters properly (Michael Meskes)
- Fix performance regression in `contrib/dblink` connection startup (Joe Conway)

  Avoid an unnecessary round trip when client and server encodings match.
- In `contrib/isn`, fix incorrect calculation of the check digit for ISMN values (Fabien Coelho)
- Fix `contrib/pgbench`'s progress logging to avoid overflow when the scale factor is large (Tatsuo Ishii)
- Fix `contrib/pg_stat_statement`'s handling of `CURRENT_DATE` and related constructs (Kyotaro Horiguchi)
- Improve lost-connection error handling in `contrib/postgres_fdw` (Tom Lane)
- Ensure client-code-only installation procedure works as documented (Peter Eisentraut)
- In Mingw and Cygwin builds, install the libpq DLL in the `bin` directory (Andrew Dunstan)

This duplicates what the MSVC build has long done. It should fix problems with programs like psql failing to start because they can't find the DLL.

- Avoid using the deprecated `dllwrap` tool in Cygwin builds (Marco Atzeri)
- Enable building with Visual Studio 2013 (Brar Piening)
- Don't generate plain-text `HISTORY` and `src/test/regress/README` files anymore (Tom Lane)

  These text files duplicated the main HTML and PDF documentation formats. The trouble involved in maintaining them greatly outweighs the likely audience for plain-text format. Distribution tarballs will still contain files by these names, but they'll just be stubs directing the reader to consult the main documentation. The plain-text `INSTALL` file will still be maintained, as there is arguably a use-case for that.
- Update time zone data files to tzdata release 2013i for DST law changes in Jordan and historical changes in Cuba.

  In addition, the zones `Asia/Riyadh87`, `Asia/Riyadh88`, and `Asia/Riyadh89` have been removed, as they are no longer maintained by IANA, and never represented actual civil timekeeping practice.

E.7. Release 9.3.2

Release Date: 2013-12-05

This release contains a variety of fixes from 9.3.1. For information about new features in the 9.3 major release, see Section E.9.

E.7.1. Migration to Version 9.3.2

A dump/restore is not required for those running 9.3.X.

However, this release corrects a number of potential data corruption issues. See the first three changelog entries below to find out whether your installation has been affected and what steps you can take if so.

Also, if you are upgrading from a version earlier than 9.3.1, see Section E.8.

E.7.2. Changes

- Fix `VACUUM`'s tests to see whether it can update `relfrozenxid` (Andres Freund)

  In some cases `VACUUM` (either manual or autovacuum) could incorrectly advance a table's `relfrozenxid` value, allowing tuples to escape freezing, causing those rows to become invisible once 2^31 transactions have elapsed. The probability of data loss is fairly low since multiple incorrect advancements would need to happen before actual loss occurs, but it's not zero. In 9.2.0 and later, the probability of loss is higher, and it's also possible to get "could not access status of transaction" errors as a consequence of this bug. Users upgrading from releases 9.0.4 or 8.4.8 or earlier are not affected, but all later versions contain the bug.

The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix any latent corruption but will not be able to fix all pre-existing data errors. However, an installation can be presumed safe after performing this vacuuming if it has executed fewer than 2^31 update transactions in its lifetime (check this with `SELECT txid_current() < 2^31`).

- Fix multiple bugs in MultiXactId freezing (Andres Freund, Álvaro Herrera)

  These bugs could lead to "could not access status of transaction" errors, or to duplicate or vanishing rows. Users upgrading from releases prior to 9.3.0 are not affected.

  The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix latent corruption but will not be able to fix all pre-existing data errors.

  As a separate issue, these bugs can also cause standby servers to get out of sync with the primary, thus exhibiting data errors that are not in the primary. Therefore, it's recommended that 9.3.0 and 9.3.1 standby servers be re-cloned from the primary (e.g., with a new base backup) after upgrading.

- Fix initialization of `pg_clog` and `pg_subtrans` during hot standby startup (Andres Freund, Heikki Linnakangas)

  This bug can cause data loss on standby servers at the moment they start to accept hot-standby queries, by marking committed transactions as uncommitted. The likelihood of such corruption is small unless, at the time of standby startup, the primary server has executed many updating transactions since its last checkpoint. Symptoms include missing rows, rows that should have been deleted being still visible, and obsolete versions of updated rows being still visible alongside their newer versions.

  This bug was introduced in versions 9.3.0, 9.2.5, 9.1.10, and 9.0.14. Standby servers that have only been running earlier releases are not at risk. It's recommended that standby servers that have ever run any of the buggy releases be re-cloned from the primary (e.g., with a new base backup) after upgrading.

- Fix multiple bugs in update chain traversal (Andres Freund, Álvaro Herrera)

  These bugs could result in incorrect behavior, such as locking or even updating the wrong row, in the presence of concurrent updates. Spurious "unable to fetch updated version of tuple" errors were also possible.

- Fix dangling-pointer problem in fast-path locking (Tom Lane)

  This could lead to corruption of the lock data structures in shared memory, causing "lock already held" and other odd errors.

- Fix assorted race conditions in timeout management (Tom Lane)

  These errors could result in a server process becoming unresponsive because it had blocked SIGALRM and/or SIGINT.

- Truncate `pg_multixact` contents during WAL replay (Andres Freund)

  This avoids ever-increasing disk space consumption in standby servers.

- Ensure an anti-wraparound `VACUUM` counts a page as scanned when it's only verified that no tuples need freezing (Sergey Burladyan, Jeff Janes)

  This bug could result in failing to advance `relfrozenxid`, so that the table would still be thought to need another anti-wraparound vacuum. In the worst case the database might even shut down to prevent wraparound.

- Fix full-table-vacuum request mechanism for MultiXactIds (Andres Freund)

This bug could result in large amounts of useless autovacuum activity.

- Fix race condition in GIN index posting tree page deletion (Heikki Linnakangas)

  This could lead to transient wrong answers or query failures.

- Fix "unexpected spgdoinsert() failure" error during SP-GiST index creation (Teodor Sigaev)
- Fix assorted bugs in materialized views (Kevin Grittner, Andres Freund)
- Re-allow duplicate table aliases if they're within aliased JOINs (Tom Lane)

  Historically PostgreSQL has accepted queries like

  ```
  SELECT ... FROM tab1 x CROSS JOIN (tab2 x CROSS JOIN tab3 y) z
  ```

  although a strict reading of the SQL standard would forbid the duplicate usage of table alias `x`. A misguided change in 9.3.0 caused it to reject some such cases that were formerly accepted. Restore the previous behavior.

- Avoid flattening a subquery whose `SELECT` list contains a volatile function wrapped inside a sub-`SELECT` (Tom Lane)

  This avoids unexpected results due to extra evaluations of the volatile function.

- Fix planner's processing of non-simple-variable subquery outputs nested within outer joins (Tom Lane)

  This error could lead to incorrect plans for queries involving multiple levels of subqueries within `JOIN` syntax.

- Fix incorrect planning in cases where the same non-strict expression appears in multiple `WHERE` and outer `JOIN` equality clauses (Tom Lane)
- Fix planner crash with whole-row reference to a subquery (Tom Lane)
- Fix incorrect generation of optimized MIN()/MAX() plans for inheritance trees (Tom Lane)

  The planner could fail in cases where the MIN()/MAX() argument was an expression rather than a simple variable.

- Fix premature deletion of temporary files (Andres Freund)
- Prevent intra-transaction memory leak when printing range values (Tom Lane)

  This fix actually cures transient memory leaks in any datatype output function, but range types are the only ones known to have had a significant problem.

- Fix memory leaks when reloading configuration files (Heikki Linnakangas, Hari Babu)
- Prevent incorrect display of dropped columns in NOT NULL and CHECK constraint violation messages (Michael Paquier and Tom Lane)
- Allow default arguments and named-argument notation for window functions (Tom Lane)

  Previously, these cases were likely to crash.

- Suppress trailing whitespace on each line when pretty-printing rules and views (Tom Lane)

  9.3.0 generated such whitespace in many more cases than previous versions did. To reduce unexpected behavioral changes, suppress unnecessary whitespace in all cases.

- Fix possible read past end of memory in rule printing (Peter Eisentraut)
- Fix array slicing of `int2vector` and `oidvector` values (Tom Lane)

  Expressions of this kind are now implicitly promoted to regular `int2` or `oid` arrays.

- Return a valid JSON value when converting an empty `hstore` value to `json` (Oskari Saarenmaa)
- Fix incorrect behaviors when using a SQL-standard, simple GMT offset timezone (Tom Lane)

In some cases, the system would use the simple GMT offset value when it should have used the regular timezone setting that had prevailed before the simple offset was selected. This change also causes the `timeofday` function to honor the simple GMT offset zone.

- Prevent possible misbehavior when logging translations of Windows error codes (Tom Lane)
- Properly quote generated command lines in pg_ctl (Naoya Anzai and Tom Lane)

  This fix applies only to Windows.
- Fix pg_dumpall to work when a source database sets `default_transaction_read_only` via `ALTER DATABASE SET` (Kevin Grittner)

  Previously, the generated script would fail during restore.
- Fix pg_isready to handle its `-d` option properly (Fabrízio de Royes Mello and Fujii Masao)
- Fix parsing of WAL file names in pg_receivexlog (Heikki Linnakangas)

  This error made pg_receivexlog unable to restart streaming after stopping, once at least 4 GB of WAL had been written.
- Report out-of-disk-space failures properly in pg_upgrade (Peter Eisentraut)
- Make ecpg search for quoted cursor names case-sensitively (Zoltán Böszörményi)
- Fix ecpg's processing of lists of variables declared `varchar` (Zoltán Böszörményi)
- Make `contrib/lo` defend against incorrect trigger definitions (Marc Cousin)
- Update time zone data files to tzdata release 2013h for DST law changes in Argentina, Brazil, Jordan, Libya, Liechtenstein, Morocco, and Palestine. Also, new timezone abbreviations WIB, WIT, WITA for Indonesia.

E.8. Release 9.3.1

Release Date: 2013-10-10

This release contains a variety of fixes from 9.3.0. For information about new features in the 9.3 major release, see Section E.9.

E.8.1. Migration to Version 9.3.1

A dump/restore is not required for those running 9.3.X.

However, if you use the `hstore` extension, see the first changelog entry.

E.8.2. Changes

- Ensure new-in-9.3 JSON functionality is added to the `hstore` extension during an update (Andrew Dunstan)

  Users who upgraded a pre-9.3 database containing `hstore` should execute

  ```
  ALTER EXTENSION hstore UPDATE;
  ```

after installing 9.3.1, to add two new JSON functions and a cast. (If `hstore` is already up to date, this command does nothing.)

- Fix memory leak when creating B-tree indexes on range columns (Heikki Linnakangas)
- Fix memory leak caused by `lo_open()` failure (Heikki Linnakangas)
- Serializable snapshot fixes (Kevin Grittner, Heikki Linnakangas)
- Fix deadlock bug in libpq when using SSL (Stephen Frost)
- Fix timeline handling bugs in pg_receivexlog (Heikki Linnakangas, Andrew Gierth)
- Prevent `CREATE FUNCTION` from checking `SET` variables unless function body checking is enabled (Tom Lane)
- Remove rare inaccurate warning during vacuum of index-less tables (Heikki Linnakangas)

E.9. Release 9.3

Release Date: 2013-09-09

E.9.1. Overview

Major enhancements in PostgreSQL 9.3 include:

- Add materialized views
- Make simple views auto-updatable
- Add many features for the `JSON` data type, including operators and functions to extract elements from `JSON` values
- Implement SQL-standard `LATERAL` option for `FROM`-clause subqueries and function calls
- Allow foreign data wrappers to support writes (inserts/updates/deletes) on foreign tables
- Add a Postgres foreign data wrapper to allow access to other Postgres servers
- Add support for event triggers
- Add optional ability to checksum data pages and report corruption
- Prevent non-key-field row updates from blocking foreign key checks
- Greatly reduce System V shared memory requirements

The above items are explained in more detail in the sections below.

E.9.2. Migration to Version 9.3

A dump/restore using pg_dumpall, or use of pg_upgrade, is required for those wishing to migrate data from any previous release.

Version 9.3 contains a number of changes that may affect compatibility with previous releases. Observe the following incompatibilities:

E.9.2.1. Server Settings

- Rename `replication_timeout` to `wal_sender_timeout` (Amit Kapila)

  This setting controls the WAL sender timeout.

- Require superuser privileges to set `commit_delay` because it can now potentially delay other sessions (Simon Riggs)

- Allow in-memory sorts to use their full memory allocation (Jeff Janes)

  Users who have set `work_mem` based on the previous behavior may need to revisit that setting.

E.9.2.2. Other

- Throw an error if a tuple to be updated or deleted has already been updated or deleted by a `BEFORE` trigger (Kevin Grittner)

  Formerly, the originally-intended update was silently skipped, resulting in logical inconsistency since the trigger might have propagated data to other places based on the intended update. Now an error is thrown to prevent the inconsistent results from being committed. If this change affects your application, the best solution is usually to move the data-propagation actions to an `AFTER` trigger.

  This error will also be thrown if a query invokes a volatile function that modifies rows that are later modified by the query itself. Such cases likewise previously resulted in silently skipping updates.

- Change multicolumn `ON UPDATE SET NULL/SET DEFAULT` foreign key actions to affect all columns of the constraint, not just those changed in the `UPDATE` (Tom Lane)

  Previously, we would set only those referencing columns that correspond to referenced columns that were changed by the `UPDATE`. This was what was required by SQL-92, but more recent editions of the SQL standard specify the new behavior.

- Force cached plans to be replanned if the `search_path` changes (Tom Lane)

  Previously, cached plans already generated in the current session were not redone if the query was re-executed with a new `search_path` setting, resulting in surprising behavior.

- Fix `to_number()` to properly handle a period used as a thousands separator (Tom Lane)

  Previously, a period was considered to be a decimal point even when the locale says it isn't and the `D` format code is used to specify use of the locale-specific decimal point. This resulted in wrong answers if `FM` format was also used.

- Fix `STRICT` non-set-returning functions that have set-returning functions in their arguments to properly return null rows (Tom Lane)

  A null value passed to the strict function should result in a null output, but instead, that output row was suppressed entirely.

- Store WAL in a continuous stream, rather than skipping the last 16MB segment every 4GB (Heikki Linnakangas)

  Previously, WAL files with names ending in `FF` were not used because of this skipping. If you have WAL backup or restore scripts that took this behavior into account, they will need to be adjusted.

- In `pg_constraint.confmatchtype`, store the default foreign key match type (non-`FULL`, non-`PARTIAL`) as `s` for "simple" (Tom Lane)

  Previously this case was represented by `u` for "unspecified".

E.9.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 9.3 and the previous major release.

E.9.3.1. Server

E.9.3.1.1. Locking

- Prevent non-key-field row updates from blocking foreign key checks (Álvaro Herrera, Noah Misch, Andres Freund, Alexander Shulgin, Marti Raudsepp, Alexander Shulgin)

  This change improves concurrency and reduces the probability of deadlocks when updating tables involved in a foreign-key constraint. `UPDATE`s that do not change any columns referenced in a foreign key now take the new `NO KEY UPDATE` lock mode on the row, while foreign key checks use the new `KEY SHARE` lock mode, which does not conflict with `NO KEY UPDATE`. So there is no blocking unless a foreign-key column is changed.
- Add configuration variable `lock_timeout` to allow limiting how long a session will wait to acquire any one lock (Zoltán Böszörményi)

E.9.3.1.2. Indexes

- Add SP-GiST support for range data types (Alexander Korotkov)
- Allow GiST indexes to be unlogged (Jeevan Chalke)
- Improve performance of GiST index insertion by randomizing the choice of which page to descend to when there are multiple equally good alternatives (Heikki Linnakangas)
- Improve concurrency of hash index operations (Robert Haas)

E.9.3.1.3. Optimizer

- Collect and use histograms of upper and lower bounds, as well as range lengths, for range types (Alexander Korotkov)
- Improve optimizer's cost estimation for index access (Tom Lane)
- Improve optimizer's hash table size estimate for doing `DISTINCT` via hash aggregation (Tom Lane)
- Suppress no-op Result and Limit plan nodes (Kyotaro Horiguchi, Amit Kapila, Tom Lane)
- Reduce optimizer overhead by not keeping plans on the basis of cheap startup cost when the optimizer only cares about total cost overall (Tom Lane)

E.9.3.1.4. General Performance

- Add `COPY FREEZE` option to avoid the overhead of marking tuples as frozen later (Simon Riggs, Jeff Davis)
- Improve performance of `NUMERIC` calculations (Kyotaro Horiguchi)
- Improve synchronization of sessions waiting for `commit_delay` (Peter Geoghegan)

This greatly improves the usefulness of `commit_delay`.

- Improve performance of the `CREATE TEMPORARY TABLE ... ON COMMIT DELETE ROWS` option by not truncating such temporary tables in transactions that haven't touched any temporary tables (Heikki Linnakangas)
- Make vacuum recheck visibility after it has removed expired tuples (Pavan Deolasee)

  This increases the chance of a page being marked as all-visible.
- Add per-resource-owner lock caches (Jeff Janes)

  This speeds up lock bookkeeping at statement completion in multi-statement transactions that hold many locks; it is particularly useful for pg_dump.
- Avoid scanning the entire relation cache at commit of a transaction that creates a new relation (Jeff Janes)

  This speeds up sessions that create many tables in successive small transactions, such as a pg_restore run.
- Improve performance of transactions that drop many relations (Tomas Vondra)

E.9.3.1.5. Monitoring

- Add optional ability to checksum data pages and report corruption (Simon Riggs, Jeff Davis, Greg Smith, Ants Aasma)

  The checksum option can be set during initdb.
- Split the statistics collector's data file into separate global and per-database files (Tomas Vondra)

  This reduces the I/O required for statistics tracking.
- Fix the statistics collector to operate properly in cases where the system clock goes backwards (Tom Lane)

  Previously, statistics collection would stop until the time again reached the latest time previously recorded.
- Emit an informative message to postmaster standard error when we are about to stop logging there (Tom Lane)

  This should help reduce user confusion about where to look for log output in common configurations that log to standard error only during postmaster startup.

E.9.3.1.6. Authentication

- When an authentication failure occurs, log the relevant `pg_hba.conf` line, to ease debugging of unintended failures (Magnus Hagander)
- Improve LDAP error reporting and documentation (Peter Eisentraut)
- Add support for specifying LDAP authentication parameters in URL format, per RFC 4516 (Peter Eisentraut)
- Change the `ssl_ciphers` parameter to start with `DEFAULT`, rather than `ALL`, then remove insecure ciphers (Magnus Hagander)

  This should yield a more appropriate SSL cipher set.
- Parse and load `pg_ident.conf` once, not during each connection (Amit Kapila)

This is similar to how `pg_hba.conf` is processed.

E.9.3.1.7. Server Settings

- Greatly reduce System V shared memory requirements (Robert Haas)

  On Unix-like systems, `mmap()` is now used for most of PostgreSQL's shared memory. For most users, this will eliminate any need to adjust kernel parameters for shared memory.

- Allow the postmaster to listen on multiple Unix-domain sockets (Honza Horák)

  The configuration parameter `unix_socket_directory` is replaced by `unix_socket_directories`, which accepts a list of directories.

- Allow a directory of configuration files to be processed (Magnus Hagander, Greg Smith, Selena Deckelmann)

  Such a directory is specified with `include_dir` in the server configuration file.

- Increase the maximum initdb-configured value for `shared_buffers` to 128MB (Robert Haas)

  This is the maximum value that initdb will attempt to set in `postgresql.conf`; the previous maximum was 32MB.

- Remove the external PID file, if any, on postmaster exit (Peter Eisentraut)

E.9.3.2. Replication and Recovery

- Allow a streaming replication standby to follow a timeline switch (Heikki Linnakangas)

  This allows streaming standby servers to receive WAL data from a slave newly promoted to master status. Previously, other standbys would require a resync to begin following the new master.

- Add SQL functions `pg_is_in_backup()` and `pg_backup_start_time()` (Gilles Darold)

  These functions report the status of base backups.

- Improve performance of streaming log shipping with `synchronous_commit` disabled (Andres Freund)

- Allow much faster promotion of a streaming standby to primary (Simon Riggs, Kyotaro Horiguchi)

- Add the last checkpoint's redo location to pg_controldata's output (Fujii Masao)

  This information is useful for determining which WAL files are needed for restore.

- Allow tools like pg_receivexlog to run on computers with different architectures (Heikki Linnakangas)

  WAL files can still only be replayed on servers with the same architecture as the primary; but they can now be transmitted to and stored on machines of any architecture, since the streaming replication protocol is now machine-independent.

- Make pg_basebackup `--write-recovery-conf` output a minimal `recovery.conf` file (Zoltán Böszörményi, Magnus Hagander)

  This simplifies setting up a standby server.

- Allow pg_receivexlog and pg_basebackup `--xlog-method` to handle streaming timeline switches (Heikki Linnakangas)

- Add `wal_receiver_timeout` parameter to control the WAL receiver's timeout (Amit Kapila)

  This allows more rapid detection of connection failure.

- Change the WAL record format to allow splitting the record header across pages (Heikki Linnakangas)

  The new format is slightly more compact, and is more efficient to write.

E.9.3.3. Queries

- Implement SQL-standard `LATERAL` option for `FROM`-clause subqueries and function calls (Tom Lane)

  This feature allows subqueries and functions in `FROM` to reference columns from other tables in the `FROM` clause. The `LATERAL` keyword is optional for functions.

- Add support for piping `COPY` and psql `\copy` data to/from an external program (Etsuro Fujita)

- Allow a multirow `VALUES` clause in a rule to reference `OLD`/`NEW` (Tom Lane)

E.9.3.4. Object Manipulation

- Add support for event triggers (Dimitri Fontaine, Robert Haas, Álvaro Herrera)

  This allows server-side functions written in event-enabled languages to be called when DDL commands are run.

- Allow foreign data wrappers to support writes (inserts/updates/deletes) on foreign tables (KaiGai Kohei)

- Add `CREATE SCHEMA ... IF NOT EXISTS` clause (Fabrízio de Royes Mello)

- Make `REASSIGN OWNED` also change ownership of shared objects (Álvaro Herrera)

- Make `CREATE AGGREGATE` complain if the given initial value string is not valid input for the transition datatype (Tom Lane)

- Suppress `CREATE TABLE`'s messages about implicit index and sequence creation (Robert Haas)

  These messages now appear at `DEBUG1` verbosity, so that they will not be shown by default.

- Allow `DROP TABLE IF EXISTS` to succeed when a non-existent schema is specified in the table name (Bruce Momjian)

  Previously, it threw an error if the schema did not exist.

- Provide clients with constraint violation details as separate fields (Pavel Stehule)

  This allows clients to retrieve table, column, data type, or constraint name error details. Previously such information had to be extracted from error strings. Client library support is required to access these fields.

E.9.3.4.1. `ALTER`

- Support `IF NOT EXISTS` option in `ALTER TYPE ... ADD VALUE` (Andrew Dunstan)

  This is useful for conditionally adding values to enumerated types.

- Add `ALTER ROLE ALL SET` to establish settings for all users (Peter Eisentraut)

This allows settings to apply to all users in all databases. `ALTER DATABASE SET` already allowed addition of settings for all users in a single database. `postgresql.conf` has a similar effect.

- Add support for `ALTER RULE ... RENAME` (Ali Dar)

E.9.3.4.2. VIEWs

- Add materialized views (Kevin Grittner)

  Unlike ordinary views, where the base tables are read on every access, materialized views create physical tables at creation or refresh time. Access to the materialized view then reads from its physical table. There is not yet any facility for incrementally refreshing materialized views or auto-accessing them via base table access.

- Make simple views auto-updatable (Dean Rasheed)

  Simple views that reference some or all columns from a single base table are now updatable by default. More complex views can be made updatable using `INSTEAD OF` triggers or `INSTEAD` rules.

- Add `CREATE RECURSIVE VIEW` syntax (Peter Eisentraut)

  Internally this is translated into `CREATE VIEW ... WITH RECURSIVE ...`.

- Improve view/rule printing code to handle cases where referenced tables are renamed, or columns are renamed, added, or dropped (Tom Lane)

  Table and column renamings can produce cases where, if we merely substitute the new name into the original text of a rule or view, the result is ambiguous. This change fixes the rule-dumping code to insert manufactured table and column aliases when needed to preserve the original semantics.

E.9.3.5. Data Types

- Increase the maximum size of large objects from 2GB to 4TB (Nozomi Anzai, Yugo Nagata)

  This change includes adding 64-bit-capable large object access functions, both in the server and in libpq.

- Allow text timezone designations, e.g. "America/Chicago", in the "T" field of ISO-format `timestamptz` input (Bruce Momjian)

E.9.3.5.1. JSON

- Add operators and functions to extract elements from `JSON` values (Andrew Dunstan)
- Allow `JSON` values to be converted into records (Andrew Dunstan)
- Add functions to convert scalars, records, and `hstore` values to `JSON` (Andrew Dunstan)

E.9.3.6. Functions

- Add `array_remove()` and `array_replace()` functions (Marco Nenciarini, Gabriele Bartolini)

- Allow `concat()` and `format()` to properly expand `VARIADIC`-labeled arguments (Pavel Stehule)
- Improve `format()` to provide field width and left/right alignment options (Pavel Stehule)
- Make `to_char()`, `to_date()`, and `to_timestamp()` handle negative (BC) century values properly (Bruce Momjian)

  Previously the behavior was either wrong or inconsistent with positive/AD handling, e.g. with the format mask "IYYY-IW-DY".
- Make `to_date()` and `to_timestamp()` return proper results when mixing ISO and Gregorian week/day designations (Bruce Momjian)
- Cause `pg_get_viewdef()` to start a new line by default after each `SELECT` target list entry and `FROM` entry (Marko Tiikkaja)

  This reduces line length in view printing, for instance in pg_dump output.
- Fix `map_sql_value_to_xml_value()` to print values of domain types the same way their base type would be printed (Pavel Stehule)

  There are special formatting rules for certain built-in types such as `boolean`; these rules now also apply to domains over these types.

E.9.3.7. Server-Side Languages

E.9.3.7.1. PL/pgSQL Server-Side Language

- Allow PL/pgSQL to use `RETURN` with a composite-type expression (Asif Rehman)

  Previously, in a function returning a composite type, `RETURN` could only reference a variable of that type.
- Allow PL/pgSQL to access constraint violation details as separate fields (Pavel Stehule)
- Allow PL/pgSQL to access the number of rows processed by `COPY` (Pavel Stehule)

  A `COPY` executed in a PL/pgSQL function now updates the value retrieved by `GET DIAGNOSTICS x = ROW_COUNT`.
- Allow unreserved keywords to be used as identifiers everywhere in PL/pgSQL (Tom Lane)

  In certain places in the PL/pgSQL grammar, keywords had to be quoted to be used as identifiers, even if they were nominally unreserved.

E.9.3.7.2. PL/Python Server-Side Language

- Add PL/Python result object string handler (Peter Eisentraut)

  This allows `plpy.debug(rv)` to output something reasonable.
- Make PL/Python convert OID values to a proper Python numeric type (Peter Eisentraut)
- Handle SPI errors raised explicitly (with PL/Python's `RAISE`) the same as internal SPI errors (Oskari Saarenmaa and Jan Urbanski)

E.9.3.8. Server Programming Interface (SPI)

- Prevent leakage of SPI tuple tables during subtransaction abort (Tom Lane)

  At the end of any failed subtransaction, the core SPI code now releases any SPI tuple tables that were created during that subtransaction. This avoids the need for SPI-using code to keep track of such tuple tables and release them manually in error-recovery code. Failure to do so caused a number of transaction-lifespan memory leakage issues in PL/pgSQL and perhaps other SPI clients. `SPI_freetuptable()` now protects itself against multiple freeing requests, so any existing code that did take care to clean up shouldn't be broken by this change.
- Allow SPI functions to access the number of rows processed by `COPY` (Pavel Stehule)

E.9.3.9. Client Applications

- Add command-line utility pg_isready to check if the server is ready to accept connections (Phil Sorber)
- Support multiple `--table` arguments for pg_restore, clusterdb, reindexdb, and vacuumdb (Josh Kupershmidt)

  This is similar to the way pg_dump's `--table` option works.
- Add `--dbname` option to pg_dumpall, pg_basebackup, and pg_receivexlog to allow specifying a connection string (Amit Kapila)
- Add libpq function `PQconninfo()` to return connection information (Zoltán Böszörményi, Magnus Hagander)

E.9.3.9.1. psql

- Adjust function cost settings so psql tab completion and pattern searching are more efficient (Tom Lane)
- Improve psql's tab completion coverage (Jeff Janes, Dean Rasheed, Peter Eisentraut, Magnus Hagander)
- Allow the psql `--single-transaction` mode to work when reading from standard input (Fabien Coelho, Robert Haas)

  Previously this option only worked when reading from a file.
- Remove psql warning when connecting to an older server (Peter Eisentraut)

  A warning is still issued when connecting to a server of a newer major version than psql's.

E.9.3.9.1.1. Backslash Commands

- Add psql command `\watch` to repeatedly execute a SQL command (Will Leinweber)
- Add psql command `\gset` to store query results in psql variables (Pavel Stehule)
- Add SSL information to psql's `\conninfo` command (Alastair Turner)
- Add "Security" column to psql's `\df+` output (Jon Erdman)
- Allow psql command `\l` to accept a database name pattern (Peter Eisentraut)
- In psql, do not allow `\connect` to use defaults if there is no active connection (Bruce Momjian)

This might be the case if the server had crashed.

- Properly reset state after failure of a SQL command executed with psql's `\g file` (Tom Lane)

  Previously, the output from subsequent SQL commands would unexpectedly continue to go to the same file.

E.9.3.9.1.2. Output

- Add a `latex-longtable` output format to psql (Bruce Momjian)

  This format allows tables to span multiple pages.

- Add a `border=3` output mode to the psql `latex` format (Bruce Momjian)
- In psql's tuples-only and expanded output modes, no longer emit "(No rows)" for zero rows (Peter Eisentraut)
- In psql's unaligned, expanded output mode, no longer print an empty line for zero rows (Peter Eisentraut)

E.9.3.9.2. pg_dump

- Add pg_dump `--jobs` option to dump tables in parallel (Joachim Wieland)
- Make pg_dump output functions in a more predictable order (Joel Jacobson)
- Fix tar files emitted by pg_dump to be POSIX conformant (Brian Weaver, Tom Lane)
- Add `--dbname` option to pg_dump, for consistency with other client commands (Heikki Linnakangas)

  The database name could already be supplied last without a flag.

E.9.3.9.3. initdb

- Make initdb fsync the newly created data directory (Jeff Davis)

  This insures data integrity in event of a system crash shortly after initdb. This can be disabled by using `--nosync`.

- Add initdb `--sync-only` option to sync the data directory to durable storage (Bruce Momjian)

  This is used by pg_upgrade.

- Make initdb issue a warning about placing the data directory at the top of a file system mount point (Bruce Momjian)

E.9.3.10. Source Code

- Add infrastructure to allow plug-in background worker processes (Álvaro Herrera)
- Create a centralized timeout API (Zoltán Böszörményi)

- Create libpgcommon and move `pg_malloc()` and other functions there (Álvaro Herrera, Andres Freund)

  This allows libpgport to be used solely for portability-related code.
- Add support for list links embedded in larger structs (Andres Freund)
- Use `SA_RESTART` for all signals, including `SIGALRM` (Tom Lane)
- Ensure that the correct text domain is used when translating `errcontext()` messages (Heikki Linnakangas)
- Standardize naming of client-side memory allocation functions (Tom Lane)
- Provide support for "static assertions" that will fail at compile time if some compile-time-constant condition is not met (Andres Freund, Tom Lane)
- Support `Assert()` in client-side code (Andrew Dunstan)
- Add decoration to inform the C compiler that some `ereport()` and `elog()` calls do not return (Peter Eisentraut, Andres Freund, Tom Lane, Heikki Linnakangas)
- Allow options to be passed to the regression test output comparison utility via `PG_REGRESS_DIFF_OPTS` (Peter Eisentraut)
- Add isolation tests for `CREATE INDEX CONCURRENTLY` (Abhijit Menon-Sen)
- Remove typedefs for `int2`/`int4` as they are better represented as `int16`/`int32` (Peter Eisentraut)
- Fix install-strip on Mac OS X (Peter Eisentraut)
- Remove configure flag `--disable-shared`, as it is no longer supported (Bruce Momjian)
- Rewrite pgindent in Perl (Andrew Dunstan)
- Provide Emacs macro to set Perl formatting to match PostgreSQL's perltidy settings (Peter Eisentraut)
- Run tool to check the keyword list whenever the backend grammar is changed (Tom Lane)
- Change the way `UESCAPE` is lexed, to significantly reduce the size of the lexer tables (Heikki Linnakangas)
- Centralize flex and bison make rules (Peter Eisentraut)

  This is useful for pgxs authors.
- Change many internal backend functions to return object `OID`s rather than void (Dimitri Fontaine)

  This is useful for event triggers.
- Invent pre-commit/pre-prepare/pre-subcommit events for transaction callbacks (Tom Lane)

  Loadable modules that use transaction callbacks might need modification to handle these new event types.
- Add function `pg_identify_object()` to produce a machine-readable description of a database object (Álvaro Herrera)
- Add post-`ALTER`-object server hooks (KaiGai Kohei)
- Implement a generic binary heap and use it for Merge-Append operations (Abhijit Menon-Sen)
- Provide a tool to help detect timezone abbreviation changes when updating the `src/timezone/data` files (Tom Lane)
- Add pkg-config support for libpq and ecpg libraries (Peter Eisentraut)
- Remove `src/tool/backend`, now that the content is on the PostgreSQL wiki (Bruce Momjian)

- Split out WAL reading as an independent facility (Heikki Linnakangas, Andres Freund)
- Use a 64-bit integer to represent WAL positions (`XLogRecPtr`) instead of two 32-bit integers (Heikki Linnakangas)

  Generally, tools that need to read the WAL format will need to be adjusted.
- Allow PL/Python to support platform-specific include directories (Peter Eisentraut)
- Allow PL/Python on OS X to build against custom versions of Python (Peter Eisentraut)

E.9.3.11. Additional Modules

- Add a Postgres foreign data wrapper contrib module to allow access to other Postgres servers (Shigeru Hanada)

  This foreign data wrapper supports writes.
- Add pg_xlogdump contrib program (Andres Freund)
- Add support for indexing of regular-expression searches in pg_trgm (Alexander Korotkov)
- Improve pg_trgm's handling of multibyte characters (Tom Lane)

  On a platform that does not have the wcstombs() or towlower() library functions, this could result in an incompatible change in the contents of pg_trgm indexes for non-ASCII data. In such cases, `REINDEX` those indexes to ensure correct search results.
- Add a pgstattuple function to report the size of the pending-insertions list of a GIN index (Fujii Masao)
- Make oid2name, pgbench, and vacuumlo set `fallback_application_name` (Amit Kapila)
- Improve output of pg_test_timing (Bruce Momjian)
- Improve output of pg_test_fsync (Peter Geoghegan)
- Create a dedicated foreign data wrapper, with its own option validator function, for dblink (Shigeru Hanada)

  When using this FDW to define the target of a dblink connection, instead of using a hard-wired list of connection options, the underlying libpq library is consulted to see what connection options it supports.

E.9.3.11.1. pg_upgrade

- Allow pg_upgrade to do dumps and restores in parallel (Bruce Momjian, Andrew Dunstan)

  This allows parallel schema dump/restore of databases, as well as parallel copy/link of data files per tablespace. Use the `--jobs` option to specify the level of parallelism.
- Make pg_upgrade create Unix-domain sockets in the current directory (Bruce Momjian, Tom Lane)

  This reduces the possibility that someone will accidentally connect during the upgrade.
- Make pg_upgrade `--check` mode properly detect the location of non-default socket directories (Bruce Momjian, Tom Lane)
- Improve performance of pg_upgrade for databases with many tables (Bruce Momjian)
- Improve pg_upgrade's logs by showing executed commands (Álvaro Herrera)
- Improve pg_upgrade's status display during copy/link (Bruce Momjian)

E.9.3.11.2. pgbench

- Add `--foreign-keys` option to pgbench (Jeff Janes)

  This adds foreign key constraints to the standard tables created by pgbench, for use in foreign key performance testing.
- Allow pgbench to aggregate performance statistics and produce output every `--aggregate-interval` seconds (Tomas Vondra)
- Add pgbench `--sampling-rate` option to control the percentage of transactions logged (Tomas Vondra)
- Reduce and improve the status message output of pgbench's initialization mode (Robert Haas, Peter Eisentraut)
- Add pgbench `-q` mode to print one output line every five seconds (Tomas Vondra)
- Output pgbench elapsed and estimated remaining time during initialization (Tomas Vondra)
- Allow pgbench to use much larger scale factors, by changing relevant columns from `integer` to `bigint` when the requested scale factor exceeds 20000 (Greg Smith)

E.9.3.12. Documentation

- Allow EPUB-format documentation to be created (Peter Eisentraut)
- Update FreeBSD kernel configuration documentation (Brad Davis)
- Improve `WINDOW` function documentation (Bruce Momjian, Florian Pflug)
- Add instructions for setting up the documentation tool chain on Mac OS X (Peter Eisentraut)
- Improve `commit_delay` documentation (Peter Geoghegan)

E.10. Release 9.2.10

Release Date: 2015-02-05

This release contains a variety of fixes from 9.2.9. For information about new features in the 9.2 major release, see Section E.20.

E.10.1. Migration to Version 9.2.10

A dump/restore is not required for those running 9.2.X.

However, if you are a Windows user and are using the "Norwegian (Bokmål)" locale, manual action is needed after the upgrade to replace any "Norwegian (Bokmål)_Norway" locale names stored in PostgreSQL system catalogs with the plain-ASCII alias "Norwegian_Norway". For details see http://wiki.postgresql.org/wiki/Changes_To_Norwegian_Locale

Also, if you are upgrading from a version earlier than 9.2.9, see Section E.11.

E.10.2. Changes

- Fix buffer overruns in `to_char()` (Bruce Momjian)

  When `to_char()` processes a numeric formatting template calling for a large number of digits, PostgreSQL would read past the end of a buffer. When processing a crafted timestamp formatting template, PostgreSQL would write past the end of a buffer. Either case could crash the server. We have not ruled out the possibility of attacks that lead to privilege escalation, though they seem unlikely. (CVE-2015-0241)

- Fix buffer overrun in replacement `*printf()` functions (Tom Lane)

  PostgreSQL includes a replacement implementation of `printf` and related functions. This code will overrun a stack buffer when formatting a floating point number (conversion specifiers `e`, `E`, `f`, `F`, `g` or `G`) with requested precision greater than about 500. This will crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. A database user can trigger such a buffer overrun through the `to_char()` SQL function. While that is the only affected core PostgreSQL functionality, extension modules that use printf-family functions may be at risk as well.

  This issue primarily affects PostgreSQL on Windows. PostgreSQL uses the system implementation of these functions where adequate, which it is on other modern platforms. (CVE-2015-0242)

- Fix buffer overruns in `contrib/pgcrypto` (Marko Tiikkaja, Noah Misch)

  Errors in memory size tracking within the `pgcrypto` module permitted stack buffer overruns and improper dependence on the contents of uninitialized memory. The buffer overrun cases can crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. (CVE-2015-0243)

- Fix possible loss of frontend/backend protocol synchronization after an error (Heikki Linnakangas)

  If any error occurred while the server was in the middle of reading a protocol message from the client, it could lose synchronization and incorrectly try to interpret part of the message's data as a new protocol message. An attacker able to submit crafted binary data within a command parameter might succeed in injecting his own SQL commands this way. Statement timeout and query cancellation are the most likely sources of errors triggering this scenario. Particularly vulnerable are applications that use a timeout and also submit arbitrary user-crafted data as binary query parameters. Disabling statement timeout will reduce, but not eliminate, the risk of exploit. Our thanks to Emil Lenngren for reporting this issue. (CVE-2015-0244)

- Fix information leak via constraint-violation error messages (Stephen Frost)

  Some server error messages show the values of columns that violate a constraint, such as a unique constraint. If the user does not have `SELECT` privilege on all columns of the table, this could mean exposing values that the user should not be able to see. Adjust the code so that values are displayed only when they came from the SQL command or could be selected by the user. (CVE-2014-8161)

- Lock down regression testing's temporary installations on Windows (Noah Misch)

  Use SSPI authentication to allow connections only from the OS user who launched the test suite. This closes on Windows the same vulnerability previously closed on other platforms, namely that other users might be able to connect to the test postmaster. (CVE-2014-0067)

- Cope with the Windows locale named "Norwegian (Bokmål)" (Heikki Linnakangas)

  Non-ASCII locale names are problematic since it's not clear what encoding they should be represented in. Map the troublesome locale name to a plain-ASCII alias, "Norwegian_Norway".

- Avoid possible data corruption if `ALTER DATABASE SET TABLESPACE` is used to move a database to a new tablespace and then shortly later move it back to its original tablespace (Tom Lane)
- Avoid corrupting tables when `ANALYZE` inside a transaction is rolled back (Andres Freund, Tom Lane, Michael Paquier)

  If the failing transaction had earlier removed the last index, rule, or trigger from the table, the table would be left in a corrupted state with the relevant `pg_class` flags not set though they should be.
- Ensure that unlogged tables are copied correctly during `CREATE DATABASE` or `ALTER DATABASE SET TABLESPACE` (Pavan Deolasee, Andres Freund)
- Fix `DROP`'s dependency searching to correctly handle the case where a table column is recursively visited before its table (Petr Jelinek, Tom Lane)

  This case is only known to arise when an extension creates both a datatype and a table using that datatype. The faulty code might refuse a `DROP EXTENSION` unless `CASCADE` is specified, which should not be required.
- Fix use-of-already-freed-memory problem in EvalPlanQual processing (Tom Lane)

  In `READ COMMITTED` mode, queries that lock or update recently-updated rows could crash as a result of this bug.
- Fix planning of `SELECT FOR UPDATE` when using a partial index on a child table (Kyotaro Horiguchi)

  In `READ COMMITTED` mode, `SELECT FOR UPDATE` must also recheck the partial index's `WHERE` condition when rechecking a recently-updated row to see if it still satisfies the query's `WHERE` condition. This requirement was missed if the index belonged to an inheritance child table, so that it was possible to incorrectly return rows that no longer satisfy the query condition.
- Fix corner case wherein `SELECT FOR UPDATE` could return a row twice, and possibly miss returning other rows (Tom Lane)

  In `READ COMMITTED` mode, a `SELECT FOR UPDATE` that is scanning an inheritance tree could incorrectly return a row from a prior child table instead of the one it should return from a later child table.
- Reject duplicate column names in the referenced-columns list of a `FOREIGN KEY` declaration (David Rowley)

  This restriction is per SQL standard. Previously we did not reject the case explicitly, but later on the code would fail with bizarre-looking errors.
- Restore previous behavior of conversion of domains to JSON (Tom Lane)

  This change causes domains over numeric and boolean to be treated like their base types for purposes of conversion to JSON. It worked like that before 9.3.5 and 9.2.9, but was unintentionally changed while fixing a related problem.
- Fix bugs in raising a `numeric` value to a large integral power (Tom Lane)

  The previous code could get a wrong answer, or consume excessive amounts of time and memory before realizing that the answer must overflow.
- In `numeric_recv()`, truncate away any fractional digits that would be hidden according to the value's `dscale` field (Tom Lane)

  A `numeric` value's display scale (`dscale`) should never be less than the number of nonzero fractional digits; but apparently there's at least one broken client application that transmits binary `numeric` values in which that's true. This leads to strange behavior since the extra digits are taken

into account by arithmetic operations even though they aren't printed. The least risky fix seems to be to truncate away such "hidden" digits on receipt, so that the value is indeed what it prints as.

- Fix incorrect search for shortest-first regular expression matches (Tom Lane)

  Matching would often fail when the number of allowed iterations is limited by a `?` quantifier or a bound expression.

- Reject out-of-range numeric timezone specifications (Tom Lane)

  Simple numeric timezone specifications exceeding +/- 168 hours (one week) would be accepted, but could then cause null-pointer dereference crashes in certain operations. There's no use-case for such large UTC offsets, so reject them.

- Fix bugs in `tsquery @> tsquery` operator (Heikki Linnakangas)

  Two different terms would be considered to match if they had the same CRC. Also, if the second operand had more terms than the first, it would be assumed not to be contained in the first; which is wrong since it might contain duplicate terms.

- Improve ispell dictionary's defenses against bad affix files (Tom Lane)

- Allow more than 64K phrases in a thesaurus dictionary (David Boutin)

  The previous coding could crash on an oversize dictionary, so this was deemed a back-patchable bug fix rather than a feature addition.

- Fix namespace handling in `xpath()` (Ali Akbar)

  Previously, the `xml` value resulting from an `xpath()` call would not have namespace declarations if the namespace declarations were attached to an ancestor element in the input `xml` value, rather than to the specific element being returned. Propagate the ancestral declaration so that the result is correct when considered in isolation.

- Ensure that whole-row variables expose nonempty column names to functions that pay attention to column names within composite arguments (Tom Lane)

  In some contexts, constructs like `row_to_json(tab.*)` may not produce the expected column names. This is fixed properly as of 9.4; in older branches, just ensure that we produce some nonempty name. (In some cases this will be the underlying table's column name rather than the query-assigned alias that should theoretically be visible.)

- Fix mishandling of system columns, particularly `tableoid`, in FDW queries (Etsuro Fujita)

- Avoid doing *`indexed_column`* `= ANY (`*`array`*`)` as an index qualifier if that leads to an inferior plan (Andrew Gierth)

  In some cases, `= ANY` conditions applied to non-first index columns would be done as index conditions even though it would be better to use them as simple filter conditions.

- Fix planner problems with nested append relations, such as inherited tables within `UNION ALL` subqueries (Tom Lane)

- Fail cleanly when a GiST index tuple doesn't fit on a page, rather than going into infinite recursion (Andrew Gierth)

- Exempt tables that have per-table `cost_limit` and/or `cost_delay` settings from autovacuum's global cost balancing rules (Álvaro Herrera)

  The previous behavior resulted in basically ignoring these per-table settings, which was unintended. Now, a table having such settings will be vacuumed using those settings, independently of what is going on in other autovacuum workers. This may result in heavier total I/O load than before, so such settings should be re-examined for sanity.

- Avoid wholesale autovacuuming when autovacuum is nominally off (Tom Lane)

  Even when autovacuum is nominally off, we will still launch autovacuum worker processes to vacuum tables that are at risk of XID wraparound. However, such a worker process then proceeded to vacuum all tables in the target database, if they met the usual thresholds for autovacuuming. This is at best pretty unexpected; at worst it delays response to the wraparound threat. Fix it so that if autovacuum is turned off, workers *only* do anti-wraparound vacuums and not any other work.

- During crash recovery, ensure that unlogged relations are rewritten as empty and are synced to disk before recovery is considered complete (Abhijit Menon-Sen, Andres Freund)

  This prevents scenarios in which unlogged relations might contain garbage data following database crash recovery.

- Fix race condition between hot standby queries and replaying a full-page image (Heikki Linnakangas)

  This mistake could result in transient errors in queries being executed in hot standby.

- Fix several cases where recovery logic improperly ignored WAL records for `COMMIT/ABORT PREPARED` (Heikki Linnakangas)

  The most notable oversight was that `recovery_min_apply_delay` failed to delay application of a two-phase commit.

- Prevent latest WAL file from being archived a second time at completion of crash recovery (Fujii Masao)

- Avoid creating unnecessary `.ready` marker files for timeline history files (Fujii Masao)

- Fix possible null pointer dereference when an empty prepared statement is used and the `log_statement` setting is `mod` or `ddl` (Fujii Masao)

- Change "pgstat wait timeout" warning message to be LOG level, and rephrase it to be more understandable (Tom Lane)

  This message was originally thought to be essentially a can't-happen case, but it occurs often enough on our slower buildfarm members to be a nuisance. Reduce it to LOG level, and expend a bit more effort on the wording: it now reads "using stale statistics instead of current ones because stats collector is not responding".

- Fix SPARC spinlock implementation to ensure correctness if the CPU is being run in a non-TSO coherency mode, as some non-Solaris kernels do (Andres Freund)

- Warn if OS X's `setlocale()` starts an unwanted extra thread inside the postmaster (Noah Misch)

- Fix processing of repeated `dbname` parameters in `PQconnectdbParams()` (Alex Shulgin)

  Unexpected behavior ensued if the first occurrence of `dbname` contained a connection string or URI to be expanded.

- Ensure that libpq reports a suitable error message on unexpected socket EOF (Marko Tiikkaja, Tom Lane)

  Depending on kernel behavior, libpq might return an empty error string rather than something useful when the server unexpectedly closed the socket.

- Clear any old error message during `PQreset()` (Heikki Linnakangas)

  If `PQreset()` is called repeatedly, and the connection cannot be re-established, error messages from the failed connection attempts kept accumulating in the `PGconn`'s error string.

- Properly handle out-of-memory conditions while parsing connection options in libpq (Alex Shulgin, Heikki Linnakangas)

- Fix array overrun in ecpg's version of `ParseDateTime()` (Michael Paquier)
- In initdb, give a clearer error message if a password file is specified but is empty (Mats Erik Andersson)
- Fix psql's `\s` command to work nicely with libedit, and add pager support (Stepan Rutz, Tom Lane)

  When using libedit rather than readline, `\s` printed the command history in a fairly unreadable encoded format, and on recent libedit versions might fail altogether. Fix that by printing the history ourselves rather than having the library do it. A pleasant side-effect is that the pager is used if appropriate.

  This patch also fixes a bug that caused newline encoding to be applied inconsistently when saving the command history with libedit. Multiline history entries written by older psql versions will be read cleanly with this patch, but perhaps not vice versa, depending on the exact libedit versions involved.
- Improve consistency of parsing of psql's special variables (Tom Lane)

  Allow variant spellings of `on` and `off` (such as `1`/`0`) for `ECHO_HIDDEN` and `ON_ERROR_ROLLBACK`. Report a warning for unrecognized values for `COMP_KEYWORD_CASE`, `ECHO`, `ECHO_HIDDEN`, `HISTCONTROL`, `ON_ERROR_ROLLBACK`, and `VERBOSITY`. Recognize all values for all these variables case-insensitively; previously there was a mishmash of case-sensitive and case-insensitive behaviors.
- Fix psql's expanded-mode display to work consistently when using `border` = 3 and `linestyle` = `ascii` or `unicode` (Stephen Frost)
- Improve performance of pg_dump when the database contains many instances of multiple dependency paths between the same two objects (Tom Lane)
- Fix pg_dumpall to restore its ability to dump from pre-8.1 servers (Gilles Darold)
- Fix possible deadlock during parallel restore of a schema-only dump (Robert Haas, Tom Lane)
- Fix core dump in `pg_dump --binary-upgrade` on zero-column composite type (Rushabh Lathia)
- Prevent WAL files created by `pg_basebackup -x/-X` from being archived again when the standby is promoted (Andres Freund)
- Fix failure of `contrib/auto_explain` to print per-node timing information when doing `EXPLAIN ANALYZE` (Tom Lane)
- Fix upgrade-from-unpackaged script for `contrib/citext` (Tom Lane)
- Fix block number checking in `contrib/pageinspect`'s `get_raw_page()` (Tom Lane)

  The incorrect checking logic could prevent access to some pages in non-main relation forks.
- Fix `contrib/pgcrypto`'s `pgp_sym_decrypt()` to not fail on messages whose length is 6 less than a power of 2 (Marko Tiikkaja)
- Fix file descriptor leak in `contrib/pg_test_fsync` (Jeff Janes)

  This could cause failure to remove temporary files on Windows.
- Handle unexpected query results, especially NULLs, safely in `contrib/tablefunc`'s `connectby()` (Michael Paquier)

  `connectby()` previously crashed if it encountered a NULL key value. It now prints that row but doesn't recurse further.
- Avoid a possible crash in `contrib/xml2`'s `xslt_process()` (Mark Simonetti)

libxslt seems to have an undocumented dependency on the order in which resources are freed; reorder our calls to avoid a crash.

- Mark some `contrib` I/O functions with correct volatility properties (Tom Lane)

  The previous over-conservative marking was immaterial in normal use, but could cause optimization problems or rejection of valid index expression definitions. Since the consequences are not large, we've just adjusted the function definitions in the extension modules' scripts, without changing version numbers.

- Numerous cleanups of warnings from Coverity static code analyzer (Andres Freund, Tatsuo Ishii, Marko Kreen, Tom Lane, Michael Paquier)

  These changes are mostly cosmetic but in some cases fix corner-case bugs, for example a crash rather than a proper error report after an out-of-memory failure. None are believed to represent security issues.

- Detect incompatible OpenLDAP versions during build (Noah Misch)

  With OpenLDAP versions 2.4.24 through 2.4.31, inclusive, PostgreSQL backends can crash at exit. Raise a warning during configure based on the compile-time OpenLDAP version number, and test the crashing scenario in the `contrib/dblink` regression test.

- In non-MSVC Windows builds, ensure `libpq.dll` is installed with execute permissions (Noah Misch)

- Make pg_regress remove any temporary installation it created upon successful exit (Tom Lane)

  This results in a very substantial reduction in disk space usage during `make check-world`, since that sequence involves creation of numerous temporary installations.

- Support time zone abbreviations that change UTC offset from time to time (Tom Lane)

  Previously, PostgreSQL assumed that the UTC offset associated with a time zone abbreviation (such as `EST`) never changes in the usage of any particular locale. However this assumption fails in the real world, so introduce the ability for a zone abbreviation to represent a UTC offset that sometimes changes. Update the zone abbreviation definition files to make use of this feature in timezone locales that have changed the UTC offset of their abbreviations since 1970 (according to the IANA timezone database). In such timezones, PostgreSQL will now associate the correct UTC offset with the abbreviation depending on the given date.

- Update time zone abbreviations lists (Tom Lane)

  Add CST (China Standard Time) to our lists. Remove references to ADT as "Arabia Daylight Time", an abbreviation that's been out of use since 2007; therefore, claiming there is a conflict with "Atlantic Daylight Time" doesn't seem especially helpful. Fix entirely incorrect GMT offsets for CKT (Cook Islands), FJT, and FJST (Fiji); we didn't even have them on the proper side of the date line.

- Update time zone data files to tzdata release 2015a.

  The IANA timezone database has adopted abbreviations of the form `AxST`/`AxDT` for all Australian time zones, reflecting what they believe to be current majority practice Down Under. These names do not conflict with usage elsewhere (other than ACST for Acre Summer Time, which has been in disuse since 1994). Accordingly, adopt these names into our "Default" timezone abbreviation set. The "Australia" abbreviation set now contains only CST, EAST, EST, SAST, SAT, and WST, all of which are thought to be mostly historical usage. Note that SAST has also been changed to be South Africa Standard Time in the "Default" abbreviation set.

  Also, add zone abbreviations SRET (Asia/Srednekolymsk) and XJT (Asia/Urumqi), and use WSST/WSDT for western Samoa. Also, there were DST law changes in Chile, Mexico, the Turks

& Caicos Islands (America/Grand_Turk), and Fiji. There is a new zone Pacific/Bougainville for portions of Papua New Guinea. Also, numerous corrections for historical (pre-1970) time zone data.

E.11. Release 9.2.9

Release Date: 2014-07-24

This release contains a variety of fixes from 9.2.8. For information about new features in the 9.2 major release, see Section E.20.

E.11.1. Migration to Version 9.2.9

A dump/restore is not required for those running 9.2.X.

However, this release corrects an index corruption problem in some GiST indexes. See the first changelog entry below to find out whether your installation has been affected and what steps you should take if so.

Also, if you are upgrading from a version earlier than 9.2.6, see Section E.14.

E.11.2. Changes

- Correctly initialize padding bytes in `contrib/btree_gist` indexes on `bit` columns (Heikki Linnakangas)

  This error could result in incorrect query results due to values that should compare equal not being seen as equal. Users with GiST indexes on `bit` or `bit varying` columns should `REINDEX` those indexes after installing this update.

- Protect against torn pages when deleting GIN list pages (Heikki Linnakangas)

  This fix prevents possible index corruption if a system crash occurs while the page update is being written to disk.

- Don't clear the right-link of a GiST index page while replaying updates from WAL (Heikki Linnakangas)

  This error could lead to transiently wrong answers from GiST index scans performed in Hot Standby.

- Fix corner-case infinite loop during insertion into an SP-GiST text index (Tom Lane)

- Fix feedback status when hot_standby_feedback is turned off on-the-fly (Simon Riggs)

- Fix possibly-incorrect cache invalidation during nested calls to `ReceiveSharedInvalidMessages` (Andres Freund)

- Fix planner's mishandling of nested PlaceHolderVars generated in nested-nestloop plans (Tom Lane)

This oversight could result in "variable not found in subplan target lists" errors, or in silently wrong query results.

- Fix "could not find pathkey item to sort" planner failures with `UNION ALL` over subqueries reading from tables with inheritance children (Tom Lane)
- Don't assume a subquery's output is unique if there's a set-returning function in its targetlist (David Rowley)

  This oversight could lead to misoptimization of constructs like `WHERE x IN (SELECT y, generate_series(1,10) FROM t GROUP BY y)`.
- Improve planner to drop constant-NULL inputs of `AND`/`OR` when possible (Tom Lane)

  This change fixes some cases where the more aggressive parameter substitution done by 9.2 and later can lead to a worse plan than older versions produced.
- Fix identification of input type category in `to_json()` and friends (Tom Lane)

  This is known to have led to inadequate quoting of `money` fields in the `JSON` result, and there may have been wrong results for other data types as well.
- Fix failure to detoast fields in composite elements of structured types (Tom Lane)

  This corrects cases where TOAST pointers could be copied into other tables without being dereferenced. If the original data is later deleted, it would lead to errors like "missing chunk number 0 for toast value ..." when the now-dangling pointer is used.
- Fix "record type has not been registered" failures with whole-row references to the output of Append plan nodes (Tom Lane)
- Fix possible crash when invoking a user-defined function while rewinding a cursor (Tom Lane)
- Fix query-lifespan memory leak while evaluating the arguments for a function in `FROM` (Tom Lane)
- Fix session-lifespan memory leaks in regular-expression processing (Tom Lane, Arthur O'Dwyer, Greg Stark)
- Fix data encoding error in `hungarian.stop` (Tom Lane)
- Prevent foreign tables from being created with OIDS when default_with_oids is true (Etsuro Fujita)
- Fix liveness checks for rows that were inserted in the current transaction and then deleted by a now-rolled-back subtransaction (Andres Freund)

  This could cause problems (at least spurious warnings, and at worst an infinite loop) if `CREATE INDEX` or `CLUSTER` were done later in the same transaction.
- Clear `pg_stat_activity.xact_start` during `PREPARE TRANSACTION` (Andres Freund)

  After the `PREPARE`, the originating session is no longer in a transaction, so it should not continue to display a transaction start time.
- Fix `REASSIGN OWNED` to not fail for text search objects (Álvaro Herrera)
- Block signals during postmaster startup (Tom Lane)

  This ensures that the postmaster will properly clean up after itself if, for example, it receives SIGINT while still starting up.
- Fix client host name lookup when processing `pg_hba.conf` entries that specify host names instead of IP addresses (Tom Lane)

  Ensure that reverse-DNS lookup failures are reported, instead of just silently not matching such entries. Also ensure that we make only one reverse-DNS lookup attempt per connection, not one per host name entry, which is what previously happened if the lookup attempts failed.

- Allow the root user to use `postgres -C variable` and `postgres --describe-config` (MauMau)

  The prohibition on starting the server as root does not need to extend to these operations, and relaxing it prevents failure of pg_ctl in some scenarios.

- Secure Unix-domain sockets of temporary postmasters started during `make check` (Noah Misch)

  Any local user able to access the socket file could connect as the server's bootstrap superuser, then proceed to execute arbitrary code as the operating-system user running the test, as we previously noted in CVE-2014-0067. This change defends against that risk by placing the server's socket in a temporary, mode 0700 subdirectory of `/tmp`. The hazard remains however on platforms where Unix sockets are not supported, notably Windows, because then the temporary postmaster must accept local TCP connections.

  A useful side effect of this change is to simplify `make check` testing in builds that override `DEFAULT_PGSOCKET_DIR`. Popular non-default values like `/var/run/postgresql` are often not writable by the build user, requiring workarounds that will no longer be necessary.

- Fix tablespace creation WAL replay to work on Windows (MauMau)

- Fix detection of socket creation failures on Windows (Bruce Momjian)

- On Windows, allow new sessions to absorb values of PGC_BACKEND parameters (such as log_connections) from the configuration file (Amit Kapila)

  Previously, if such a parameter were changed in the file post-startup, the change would have no effect.

- Properly quote executable path names on Windows (Nikhil Deshpande)

  This oversight could cause initdb and pg_upgrade to fail on Windows, if the installation path contained both spaces and `@` signs.

- Fix linking of libpython on OS X (Tom Lane)

  The method we previously used can fail with the Python library supplied by Xcode 5.0 and later.

- Avoid buffer bloat in libpq when the server consistently sends data faster than the client can absorb it (Shin-ichi Morita, Tom Lane)

  libpq could be coerced into enlarging its input buffer until it runs out of memory (which would be reported misleadingly as "lost synchronization with server"). Under ordinary circumstances it's quite far-fetched that data could be continuously transmitted more quickly than the `recv()` loop can absorb it, but this has been observed when the client is artificially slowed by scheduler constraints.

- Ensure that LDAP lookup attempts in libpq time out as intended (Laurenz Albe)

- Fix ecpg to do the right thing when an array of `char *` is the target for a FETCH statement returning more than one row, as well as some other array-handling fixes (Ashutosh Bapat)

- Fix pg_restore's processing of old-style large object comments (Tom Lane)

  A direct-to-database restore from an archive file generated by a pre-9.0 version of pg_dump would usually fail if the archive contained more than a few comments for large objects.

- Fix pg_upgrade for cases where the new server creates a TOAST table but the old version did not (Bruce Momjian)

  This rare situation would manifest as "relation OID mismatch" errors.

- Prevent `contrib/auto_explain` from changing the output of a user's `EXPLAIN` (Tom Lane)

If `auto_explain` is active, it could cause an `EXPLAIN (ANALYZE, TIMING OFF)` command to nonetheless print timing information.

- Fix query-lifespan memory leak in `contrib/dblink` (MauMau, Joe Conway)
- In `contrib/pgcrypto` functions, ensure sensitive information is cleared from stack variables before returning (Marko Kreen)
- Prevent use of already-freed memory in `contrib/pgstattuple`'s `pgstat_heap()` (Noah Misch)
- In `contrib/uuid-ossp`, cache the state of the OSSP UUID library across calls (Tom Lane)

  This improves the efficiency of UUID generation and reduces the amount of entropy drawn from `/dev/urandom`, on platforms that have that.
- Update time zone data files to tzdata release 2014e for DST law changes in Crimea, Egypt, and Morocco.

E.12. Release 9.2.8

Release Date: 2014-03-20

This release contains a variety of fixes from 9.2.7. For information about new features in the 9.2 major release, see Section E.20.

E.12.1. Migration to Version 9.2.8

A dump/restore is not required for those running 9.2.X.

However, if you are upgrading from a version earlier than 9.2.6, see Section E.14.

E.12.2. Changes

- Restore GIN metapages unconditionally to avoid torn-page risk (Heikki Linnakangas)

  Although this oversight could theoretically result in a corrupted index, it is unlikely to have caused any problems in practice, since the active part of a GIN metapage is smaller than a standard 512-byte disk sector.
- Avoid race condition in checking transaction commit status during receipt of a `NOTIFY` message (Marko Tiikkaja)

  This prevents a scenario wherein a sufficiently fast client might respond to a notification before database updates made by the notifier have become visible to the recipient.
- Allow regular-expression operators to be terminated early by query cancel requests (Tom Lane)

  This prevents scenarios wherein a pathological regular expression could lock up a server process uninterruptably for a long time.
- Remove incorrect code that tried to allow `OVERLAPS` with single-element row arguments (Joshua Yanovski)

This code never worked correctly, and since the case is neither specified by the SQL standard nor documented, it seemed better to remove it than fix it.

- Avoid getting more than `AccessShareLock` when de-parsing a rule or view (Dean Rasheed)

  This oversight resulted in pg_dump unexpectedly acquiring `RowExclusiveLock` locks on tables mentioned as the targets of `INSERT`/`UPDATE`/`DELETE` commands in rules. While usually harmless, that could interfere with concurrent transactions that tried to acquire, for example, `ShareLock` on those tables.

- Improve performance of index endpoint probes during planning (Tom Lane)

  This change fixes a significant performance problem that occurred when there were many not-yet-committed rows at the end of the index, which is a common situation for indexes on sequentially-assigned values such as timestamps or sequence-generated identifiers.

- Fix walsender's failure to shut down cleanly when client is pg_receivexlog (Fujii Masao)

- Check WAL level and hot standby parameters correctly when doing crash recovery that will be followed by archive recovery (Heikki Linnakangas)

- Fix test to see if hot standby connections can be allowed immediately after a crash (Heikki Linnakangas)

- Prevent interrupts while reporting non-`ERROR` messages (Tom Lane)

  This guards against rare server-process freezeups due to recursive entry to `syslog()`, and perhaps other related problems.

- Fix memory leak in PL/Perl when returning a composite result, including multiple-OUT-parameter cases (Alex Hunsaker)

- Fix tracking of psql script line numbers during `\copy` from out-of-line data (Kumar Rajeev Rastogi, Amit Khandekar)

  `\copy ... from` incremented the script file line number for each data line, even if the data was not coming from the script file. This mistake resulted in wrong line numbers being reported for any errors occurring later in the same script file.

- Prevent intermittent "could not reserve shared memory region" failures on recent Windows versions (MauMau)

- Update time zone data files to tzdata release 2014a for DST law changes in Fiji and Turkey, plus historical changes in Israel and Ukraine.

E.13. Release 9.2.7

Release Date: 2014-02-20

This release contains a variety of fixes from 9.2.6. For information about new features in the 9.2 major release, see Section E.20.

E.13.1. Migration to Version 9.2.7

A dump/restore is not required for those running 9.2.X.

However, if you are upgrading from a version earlier than 9.2.6, see Section E.14.

E.13.2. Changes

- Shore up `GRANT ... WITH ADMIN OPTION` restrictions (Noah Misch)

  Granting a role without `ADMIN OPTION` is supposed to prevent the grantee from adding or removing members from the granted role, but this restriction was easily bypassed by doing `SET ROLE` first. The security impact is mostly that a role member can revoke the access of others, contrary to the wishes of his grantor. Unapproved role member additions are a lesser concern, since an uncooperative role member could provide most of his rights to others anyway by creating views or `SECURITY DEFINER` functions. (CVE-2014-0060)

- Prevent privilege escalation via manual calls to PL validator functions (Andres Freund)

  The primary role of PL validator functions is to be called implicitly during `CREATE FUNCTION`, but they are also normal SQL functions that a user can call explicitly. Calling a validator on a function actually written in some other language was not checked for and could be exploited for privilege-escalation purposes. The fix involves adding a call to a privilege-checking function in each validator function. Non-core procedural languages will also need to make this change to their own validator functions, if any. (CVE-2014-0061)

- Avoid multiple name lookups during table and index DDL (Robert Haas, Andres Freund)

  If the name lookups come to different conclusions due to concurrent activity, we might perform some parts of the DDL on a different table than other parts. At least in the case of `CREATE INDEX`, this can be used to cause the permissions checks to be performed against a different table than the index creation, allowing for a privilege escalation attack. (CVE-2014-0062)

- Prevent buffer overrun with long datetime strings (Noah Misch)

  The `MAXDATELEN` constant was too small for the longest possible value of type `interval`, allowing a buffer overrun in `interval_out()`. Although the datetime input functions were more careful about avoiding buffer overrun, the limit was short enough to cause them to reject some valid inputs, such as input containing a very long timezone name. The ecpg library contained these vulnerabilities along with some of its own. (CVE-2014-0063)

- Prevent buffer overrun due to integer overflow in size calculations (Noah Misch, Heikki Linnakangas)

  Several functions, mostly type input functions, calculated an allocation size without checking for overflow. If overflow did occur, a too-small buffer would be allocated and then written past. (CVE-2014-0064)

- Prevent overruns of fixed-size buffers (Peter Eisentraut, Jozef Mlich)

  Use `strlcpy()` and related functions to provide a clear guarantee that fixed-size buffers are not overrun. Unlike the preceding items, it is unclear whether these cases really represent live issues, since in most cases there appear to be previous constraints on the size of the input string. Nonetheless it seems prudent to silence all Coverity warnings of this type. (CVE-2014-0065)

- Avoid crashing if `crypt()` returns NULL (Honza Horak, Bruce Momjian)

  There are relatively few scenarios in which `crypt()` could return NULL, but `contrib/chkpass` would crash if it did. One practical case in which this could be an issue is if libc is configured to refuse to execute unapproved hashing algorithms (e.g., "FIPS mode"). (CVE-2014-0066)

- Document risks of `make check` in the regression testing instructions (Noah Misch, Tom Lane)

Since the temporary server started by `make check` uses "trust" authentication, another user on the same machine could connect to it as database superuser, and then potentially exploit the privileges of the operating-system user who started the tests. A future release will probably incorporate changes in the testing procedure to prevent this risk, but some public discussion is needed first. So for the moment, just warn people against using `make check` when there are untrusted users on the same machine. (CVE-2014-0067)

- Fix possible mis-replay of WAL records when some segments of a relation aren't full size (Greg Stark, Tom Lane)

  The WAL update could be applied to the wrong page, potentially many pages past where it should have been. Aside from corrupting data, this error has been observed to result in significant "bloat" of standby servers compared to their masters, due to updates being applied far beyond where the end-of-file should have been. This failure mode does not appear to be a significant risk during crash recovery, only when initially synchronizing a standby created from a base backup taken from a quickly-changing master.

- Fix bug in determining when recovery has reached consistency (Tomonari Katsumata, Heikki Linnakangas)

  In some cases WAL replay would mistakenly conclude that the database was already consistent at the start of replay, thus possibly allowing hot-standby queries before the database was really consistent. Other symptoms such as "PANIC: WAL contains references to invalid pages" were also possible.

- Fix improper locking of btree index pages while replaying a `VACUUM` operation in hot-standby mode (Andres Freund, Heikki Linnakangas, Tom Lane)

  This error could result in "PANIC: WAL contains references to invalid pages" failures.

- Ensure that insertions into non-leaf GIN index pages write a full-page WAL record when appropriate (Heikki Linnakangas)

  The previous coding risked index corruption in the event of a partial-page write during a system crash.

- When `pause_at_recovery_target` and `recovery_target_inclusive` are both set, ensure the target record is applied before pausing, not after (Heikki Linnakangas)

- Fix race conditions during server process exit (Robert Haas)

  Ensure that signal handlers don't attempt to use the process's `MyProc` pointer after it's no longer valid.

- Fix race conditions in walsender shutdown logic and walreceiver SIGHUP signal handler (Tom Lane)

- Fix unsafe references to `errno` within error reporting logic (Christian Kruse)

  This would typically lead to odd behaviors such as missing or inappropriate `HINT` fields.

- Fix possible crashes from using `ereport()` too early during server startup (Tom Lane)

  The principal case we've seen in the field is a crash if the server is started in a directory it doesn't have permission to read.

- Clear retry flags properly in OpenSSL socket write function (Alexander Kukushkin)

  This omission could result in a server lockup after unexpected loss of an SSL-encrypted connection.

- Fix length checking for Unicode identifiers (`U&"..."` syntax) containing escapes (Tom Lane)

  A spurious truncation warning would be printed for such identifiers if the escaped form of the identifier was too long, but the identifier actually didn't need truncation after de-escaping.

- Allow keywords that are type names to be used in lists of roles (Stephen Frost)

  A previous patch allowed such keywords to be used without quoting in places such as role identifiers; but it missed cases where a list of role identifiers was permitted, such as `DROP ROLE`.

- Fix parser crash for `EXISTS(SELECT * FROM zero_column_table)` (Tom Lane)

- Fix possible crash due to invalid plan for nested sub-selects, such as `WHERE (... x IN (SELECT ...) ...) IN (SELECT ...)` (Tom Lane)

- Fix `UPDATE/DELETE` of an inherited target table that has `UNION ALL` subqueries (Tom Lane)

  Without this fix, `UNION ALL` subqueries aren't correctly inserted into the update plans for inheritance child tables after the first one, typically resulting in no update happening for those child table(s).

- Ensure that `ANALYZE` creates statistics for a table column even when all the values in it are "too wide" (Tom Lane)

  `ANALYZE` intentionally omits very wide values from its histogram and most-common-values calculations, but it neglected to do something sane in the case that all the sampled entries are too wide.

- In `ALTER TABLE ... SET TABLESPACE`, allow the database's default tablespace to be used without a permissions check (Stephen Frost)

  `CREATE TABLE` has always allowed such usage, but `ALTER TABLE` didn't get the memo.

- Fix "cannot accept a set" error when some arms of a `CASE` return a set and others don't (Tom Lane)

- Properly distinguish numbers from non-numbers when generating JSON output (Andrew Dunstan)

- Fix checks for all-zero client addresses in pgstat functions (Kevin Grittner)

- Fix possible misclassification of multibyte characters by the text search parser (Tom Lane)

  Non-ASCII characters could be misclassified when using C locale with a multibyte encoding. On Cygwin, non-C locales could fail as well.

- Fix possible misbehavior in `plainto_tsquery()` (Heikki Linnakangas)

  Use `memmove()` not `memcpy()` for copying overlapping memory regions. There have been no field reports of this actually causing trouble, but it's certainly risky.

- Fix placement of permissions checks in `pg_start_backup()` and `pg_stop_backup()` (Andres Freund, Magnus Hagander)

  The previous coding might attempt to do catalog access when it shouldn't.

- Accept `SHIFT_JIS` as an encoding name for locale checking purposes (Tatsuo Ishii)

- Fix `*`-qualification of named parameters in SQL-language functions (Tom Lane)

  Given a composite-type parameter named `foo`, `$1.*` worked fine, but `foo.*` not so much.

- Fix misbehavior of `PQhost()` on Windows (Fujii Masao)

  It should return `localhost` if no host has been specified.

- Improve error handling in libpq and psql for failures during `COPY TO STDOUT/FROM STDIN` (Tom Lane)

  In particular this fixes an infinite loop that could occur in 9.2 and up if the server connection was lost during `COPY FROM STDIN`. Variants of that scenario might be possible in older versions, or with other client applications.

- Fix incorrect translation handling in some psql `\d` commands (Peter Eisentraut, Tom Lane)

- Ensure pg_basebackup's background process is killed when exiting its foreground process (Magnus Hagander)
- Fix possible incorrect printing of filenames in pg_basebackup's verbose mode (Magnus Hagander)
- Avoid including tablespaces inside PGDATA twice in base backups (Dimitri Fontaine, Magnus Hagander)
- Fix misaligned descriptors in ecpg (MauMau)
- In ecpg, handle lack of a hostname in the connection parameters properly (Michael Meskes)
- Fix performance regression in `contrib/dblink` connection startup (Joe Conway)

  Avoid an unnecessary round trip when client and server encodings match.
- In `contrib/isn`, fix incorrect calculation of the check digit for ISMN values (Fabien Coelho)
- Fix `contrib/pg_stat_statement`'s handling of `CURRENT_DATE` and related constructs (Kyotaro Horiguchi)
- Ensure client-code-only installation procedure works as documented (Peter Eisentraut)
- In Mingw and Cygwin builds, install the libpq DLL in the `bin` directory (Andrew Dunstan)

  This duplicates what the MSVC build has long done. It should fix problems with programs like psql failing to start because they can't find the DLL.
- Avoid using the deprecated `dllwrap` tool in Cygwin builds (Marco Atzeri)
- Don't generate plain-text `HISTORY` and `src/test/regress/README` files anymore (Tom Lane)

  These text files duplicated the main HTML and PDF documentation formats. The trouble involved in maintaining them greatly outweighs the likely audience for plain-text format. Distribution tarballs will still contain files by these names, but they'll just be stubs directing the reader to consult the main documentation. The plain-text `INSTALL` file will still be maintained, as there is arguably a use-case for that.
- Update time zone data files to tzdata release 2013i for DST law changes in Jordan and historical changes in Cuba.

  In addition, the zones `Asia/Riyadh87`, `Asia/Riyadh88`, and `Asia/Riyadh89` have been removed, as they are no longer maintained by IANA, and never represented actual civil timekeeping practice.

E.14. Release 9.2.6

Release Date: 2013-12-05

This release contains a variety of fixes from 9.2.5. For information about new features in the 9.2 major release, see Section E.20.

E.14.1. Migration to Version 9.2.6

A dump/restore is not required for those running 9.2.X.

However, this release corrects a number of potential data corruption issues. See the first two changelog entries below to find out whether your installation has been affected and what steps you can take if so.

Also, if you are upgrading from a version earlier than 9.2.4, see Section E.16.

E.14.2. Changes

- Fix `VACUUM`'s tests to see whether it can update `relfrozenxid` (Andres Freund)

  In some cases `VACUUM` (either manual or autovacuum) could incorrectly advance a table's `relfrozenxid` value, allowing tuples to escape freezing, causing those rows to become invisible once 2^31 transactions have elapsed. The probability of data loss is fairly low since multiple incorrect advancements would need to happen before actual loss occurs, but it's not zero. In 9.2.0 and later, the probability of loss is higher, and it's also possible to get "could not access status of transaction" errors as a consequence of this bug. Users upgrading from releases 9.0.4 or 8.4.8 or earlier are not affected, but all later versions contain the bug.

  The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix any latent corruption but will not be able to fix all pre-existing data errors. However, an installation can be presumed safe after performing this vacuuming if it has executed fewer than 2^31 update transactions in its lifetime (check this with `SELECT txid_current() < 2^31`).

- Fix initialization of `pg_clog` and `pg_subtrans` during hot standby startup (Andres Freund, Heikki Linnakangas)

  This bug can cause data loss on standby servers at the moment they start to accept hot-standby queries, by marking committed transactions as uncommitted. The likelihood of such corruption is small unless, at the time of standby startup, the primary server has executed many updating transactions since its last checkpoint. Symptoms include missing rows, rows that should have been deleted being still visible, and obsolete versions of updated rows being still visible alongside their newer versions.

  This bug was introduced in versions 9.3.0, 9.2.5, 9.1.10, and 9.0.14. Standby servers that have only been running earlier releases are not at risk. It's recommended that standby servers that have ever run any of the buggy releases be re-cloned from the primary (e.g., with a new base backup) after upgrading.

- Fix dangling-pointer problem in fast-path locking (Tom Lane)

  This could lead to corruption of the lock data structures in shared memory, causing "lock already held" and other odd errors.

- Truncate `pg_multixact` contents during WAL replay (Andres Freund)

  This avoids ever-increasing disk space consumption in standby servers.

- Ensure an anti-wraparound `VACUUM` counts a page as scanned when it's only verified that no tuples need freezing (Sergey Burladyan, Jeff Janes)

  This bug could result in failing to advance `relfrozenxid`, so that the table would still be thought to need another anti-wraparound vacuum. In the worst case the database might even shut down to prevent wraparound.

- Fix race condition in GIN index posting tree page deletion (Heikki Linnakangas)

  This could lead to transient wrong answers or query failures.

- Fix "unexpected spgdoinsert() failure" error during SP-GiST index creation (Teodor Sigaev)

- Avoid flattening a subquery whose `SELECT` list contains a volatile function wrapped inside a sub-`SELECT` (Tom Lane)

  This avoids unexpected results due to extra evaluations of the volatile function.

- Fix planner's processing of non-simple-variable subquery outputs nested within outer joins (Tom Lane)

  This error could lead to incorrect plans for queries involving multiple levels of subqueries within `JOIN` syntax.

- Fix incorrect planning in cases where the same non-strict expression appears in multiple `WHERE` and outer `JOIN` equality clauses (Tom Lane)

- Fix planner crash with whole-row reference to a subquery (Tom Lane)

- Fix incorrect generation of optimized MIN()/MAX() plans for inheritance trees (Tom Lane)

  The planner could fail in cases where the MIN()/MAX() argument was an expression rather than a simple variable.

- Fix premature deletion of temporary files (Andres Freund)

- Prevent intra-transaction memory leak when printing range values (Tom Lane)

  This fix actually cures transient memory leaks in any datatype output function, but range types are the only ones known to have had a significant problem.

- Prevent incorrect display of dropped columns in NOT NULL and CHECK constraint violation messages (Michael Paquier and Tom Lane)

- Allow default arguments and named-argument notation for window functions (Tom Lane)

  Previously, these cases were likely to crash.

- Fix possible read past end of memory in rule printing (Peter Eisentraut)

- Fix array slicing of `int2vector` and `oidvector` values (Tom Lane)

  Expressions of this kind are now implicitly promoted to regular `int2` or `oid` arrays.

- Fix incorrect behaviors when using a SQL-standard, simple GMT offset timezone (Tom Lane)

  In some cases, the system would use the simple GMT offset value when it should have used the regular timezone setting that had prevailed before the simple offset was selected. This change also causes the `timeofday` function to honor the simple GMT offset zone.

- Prevent possible misbehavior when logging translations of Windows error codes (Tom Lane)

- Properly quote generated command lines in pg_ctl (Naoya Anzai and Tom Lane)

  This fix applies only to Windows.

- Fix pg_dumpall to work when a source database sets `default_transaction_read_only` via `ALTER DATABASE SET` (Kevin Grittner)

  Previously, the generated script would fail during restore.

- Make ecpg search for quoted cursor names case-sensitively (Zoltán Böszörményi)

- Fix ecpg's processing of lists of variables declared `varchar` (Zoltán Böszörményi)

- Make `contrib/lo` defend against incorrect trigger definitions (Marc Cousin)

- Update time zone data files to tzdata release 2013h for DST law changes in Argentina, Brazil, Jordan, Libya, Liechtenstein, Morocco, and Palestine. Also, new timezone abbreviations WIB, WIT, WITA for Indonesia.

E.15. Release 9.2.5

Release Date: 2013-10-10

This release contains a variety of fixes from 9.2.4. For information about new features in the 9.2 major release, see Section E.20.

E.15.1. Migration to Version 9.2.5

A dump/restore is not required for those running 9.2.X.

However, if you are upgrading from a version earlier than 9.2.4, see Section E.16.

E.15.2. Changes

- Prevent corruption of multi-byte characters when attempting to case-fold identifiers (Andrew Dunstan)

  PostgreSQL case-folds non-ASCII characters only when using a single-byte server encoding.
- Fix memory leak when creating B-tree indexes on range columns (Heikki Linnakangas)
- Fix checkpoint memory leak in background writer when `wal_level = hot_standby` (Naoya Anzai)
- Fix memory leak caused by `lo_open()` failure (Heikki Linnakangas)
- Fix memory overcommit bug when `work_mem` is using more than 24GB of memory (Stephen Frost)
- Serializable snapshot fixes (Kevin Grittner, Heikki Linnakangas)
- Fix deadlock bug in libpq when using SSL (Stephen Frost)
- Fix possible SSL state corruption in threaded libpq applications (Nick Phillips, Stephen Frost)
- Improve estimate of planner cost when choosing between generic and custom plans (Tom Lane)

  This change will favor generic plans when planning cost is high.
- Properly compute row estimates for boolean columns containing many NULL values (Andrew Gierth)

  Previously tests like `col IS NOT TRUE` and `col IS NOT FALSE` did not properly factor in NULL values when estimating plan costs.
- Fix accounting for qualifier evaluation costs in `UNION ALL` and inheritance queries (Tom Lane)

  This fixes cases where suboptimal query plans could be chosen if some `WHERE` clauses are expensive to calculate.
- Prevent pushing down `WHERE` clauses into unsafe `UNION/INTERSECT` subqueries (Tom Lane)

  Subqueries of a `UNION` or `INTERSECT` that contain set-returning functions or volatile functions in their `SELECT` lists could be improperly optimized, leading to run-time errors or incorrect query results.
- Fix rare case of "failed to locate grouping columns" planner failure (Tom Lane)
- Fix pg_dump of foreign tables with dropped columns (Andrew Dunstan)

Previously such cases could cause a pg_upgrade error.

- Reorder pg_dump processing of extension-related rules and event triggers (Joe Conway)
- Force dumping of extension tables if specified by `pg_dump -t` or `-n` (Joe Conway)
- Improve view dumping code's handling of dropped columns in referenced tables (Tom Lane)
- Fix `pg_restore -l` with the directory archive to display the correct format name (Fujii Masao)
- Properly record index comments created using `UNIQUE` and `PRIMARY KEY` syntax (Andres Freund)

  This fixes a parallel pg_restore failure.
- Cause `pg_basebackup -x` with an empty xlog directory to throw an error rather than crashing (Magnus Hagander, Haruka Takatsuka)
- Properly guarantee transmission of WAL files before clean switchover (Fujii Masao)

  Previously, the streaming replication connection might close before all WAL files had been replayed on the standby.
- Fix WAL segment timeline handling during recovery (Mitsumasa Kondo, Heikki Linnakangas)

  WAL file recycling during standby recovery could lead to premature recovery completion, resulting in data loss.
- Prevent errors in WAL replay due to references to uninitialized empty pages (Andres Freund)
- Fix `REINDEX TABLE` and `REINDEX DATABASE` to properly revalidate constraints and mark invalidated indexes as valid (Noah Misch)

  `REINDEX INDEX` has always worked properly.
- Avoid deadlocks during insertion into SP-GiST indexes (Teodor Sigaev)
- Fix possible deadlock during concurrent `CREATE INDEX CONCURRENTLY` operations (Tom Lane)
- Fix GiST index lookup crash (Tom Lane)
- Fix `regexp_matches()` handling of zero-length matches (Jeevan Chalke)

  Previously, zero-length matches like '^' could return too many matches.
- Fix crash for overly-complex regular expressions (Heikki Linnakangas)
- Fix regular expression match failures for back references combined with non-greedy quantifiers (Jeevan Chalke)
- Prevent `CREATE FUNCTION` from checking `SET` variables unless function body checking is enabled (Tom Lane)
- Allow `ALTER DEFAULT PRIVILEGES` to operate on schemas without requiring CREATE permission (Tom Lane)
- Loosen restriction on keywords used in queries (Tom Lane)

  Specifically, lessen keyword restrictions for role names, language names, `EXPLAIN` and `COPY` options, and `SET` values. This allows `COPY ... (FORMAT BINARY)` to work as expected; previously `BINARY` needed to be quoted.
- Print proper line number during `COPY` failure (Heikki Linnakangas)
- Fix `pgp_pub_decrypt()` so it works for secret keys with passwords (Marko Kreen)
- Make pg_upgrade use `pg_dump --quote-all-identifiers` to avoid problems with keyword changes between releases (Tom Lane)
- Remove rare inaccurate warning during vacuum of index-less tables (Heikki Linnakangas)

- Ensure that `VACUUM ANALYZE` still runs the ANALYZE phase if its attempt to truncate the file is cancelled due to lock conflicts (Kevin Grittner)
- Avoid possible failure when performing transaction control commands (e.g `ROLLBACK`) in prepared queries (Tom Lane)
- Ensure that floating-point data input accepts standard spellings of "infinity" on all platforms (Tom Lane)

  The C99 standard says that allowable spellings are `inf`, `+inf`, `-inf`, `infinity`, `+infinity`, and `-infinity`. Make sure we recognize these even if the platform's `strtod` function doesn't.
- Avoid unnecessary reporting when `track_activities` is off (Tom Lane)
- Expand ability to compare rows to records and arrays (Rafal Rzepecki, Tom Lane)
- Prevent crash when psql's `PSQLRC` variable contains a tilde (Bruce Momjian)
- Add spinlock support for ARM64 (Mark Salter)
- Update time zone data files to tzdata release 2013d for DST law changes in Israel, Morocco, Palestine, and Paraguay. Also, historical zone data corrections for Macquarie Island.

E.16. Release 9.2.4

Release Date: 2013-04-04

This release contains a variety of fixes from 9.2.3. For information about new features in the 9.2 major release, see Section E.20.

E.16.1. Migration to Version 9.2.4

A dump/restore is not required for those running 9.2.X.

However, this release corrects several errors in management of GiST indexes. After installing this update, it is advisable to `REINDEX` any GiST indexes that meet one or more of the conditions described below.

Also, if you are upgrading from a version earlier than 9.2.2, see Section E.18.

E.16.2. Changes

- Fix insecure parsing of server command-line switches (Mitsumasa Kondo, Kyotaro Horiguchi)

  A connection request containing a database name that begins with "-" could be crafted to damage or destroy files within the server's data directory, even if the request is eventually rejected. (CVE-2013-1899)
- Reset OpenSSL randomness state in each postmaster child process (Marko Kreen)

  This avoids a scenario wherein random numbers generated by `contrib/pgcrypto` functions might be relatively easy for another database user to guess. The risk is only significant when the

postmaster is configured with `ssl = on` but most connections don't use SSL encryption. (CVE-2013-1900)

- Make REPLICATION privilege checks test current user not authenticated user (Noah Misch)

  An unprivileged database user could exploit this mistake to call `pg_start_backup()` or `pg_stop_backup()`, thus possibly interfering with creation of routine backups. (CVE-2013-1901)

- Fix GiST indexes to not use "fuzzy" geometric comparisons when it's not appropriate to do so (Alexander Korotkov)

  The core geometric types perform comparisons using "fuzzy" equality, but `gist_box_same` must do exact comparisons, else GiST indexes using it might become inconsistent. After installing this update, users should `REINDEX` any GiST indexes on `box`, `polygon`, `circle`, or `point` columns, since all of these use `gist_box_same`.

- Fix erroneous range-union and penalty logic in GiST indexes that use `contrib/btree_gist` for variable-width data types, that is `text`, `bytea`, `bit`, and `numeric` columns (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in useless index bloat. Users are advised to `REINDEX` such indexes after installing this update.

- Fix bugs in GiST page splitting code for multi-column indexes (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in indexes that are unnecessarily inefficient to search. Users are advised to `REINDEX` multi-column GiST indexes after installing this update.

- Fix `gist_point_consistent` to handle fuzziness consistently (Alexander Korotkov)

  Index scans on GiST indexes on `point` columns would sometimes yield results different from a sequential scan, because `gist_point_consistent` disagreed with the underlying operator code about whether to do comparisons exactly or fuzzily.

- Fix buffer leak in WAL replay (Heikki Linnakangas)

  This bug could result in "incorrect local pin count" errors during replay, making recovery impossible.

- Ensure we do crash recovery before entering archive recovery, if the database was not stopped cleanly and a `recovery.conf` file is present (Heikki Linnakangas, Kyotaro Horiguchi, Mitsumasa Kondo)

  This is needed to ensure that the database is consistent in certain scenarios, such as initializing a standby server with a filesystem snapshot from a running server.

- Avoid deleting not-yet-archived WAL files during crash recovery (Heikki Linnakangas, Fujii Masao)

- Fix race condition in `DELETE RETURNING` (Tom Lane)

  Under the right circumstances, `DELETE RETURNING` could attempt to fetch data from a shared buffer that the current process no longer has any pin on. If some other process changed the buffer meanwhile, this would lead to garbage `RETURNING` output, or even a crash.

- Fix infinite-loop risk in regular expression compilation (Tom Lane, Don Porter)

- Fix potential null-pointer dereference in regular expression compilation (Tom Lane)

- Fix `to_char()` to use ASCII-only case-folding rules where appropriate (Tom Lane)

This fixes misbehavior of some template patterns that should be locale-independent, but mishandled "I" and "i" in Turkish locales.

- Fix unwanted rejection of timestamp `1999-12-31 24:00:00` (Tom Lane)
- Fix SQL-language functions to be safely usable as support functions for range types (Tom Lane)
- Fix logic error when a single transaction does `UNLISTEN` then `LISTEN` (Tom Lane)

  The session wound up not listening for notify events at all, though it surely should listen in this case.
- Fix possible planner crash after columns have been added to a view that's depended on by another view (Tom Lane)
- Fix performance issue in `EXPLAIN (ANALYZE, TIMING OFF)` (Pavel Stehule)
- Remove useless "picksplit doesn't support secondary split" log messages (Josh Hansen, Tom Lane)

  This message seems to have been added in expectation of code that was never written, and probably never will be, since GiST's default handling of secondary splits is actually pretty good. So stop nagging end users about it.
- Remove vestigial secondary-split support in `gist_box_picksplit()` (Tom Lane)

  Not only was this implementation of secondary-split not better than the default implementation, it's actually worse. So remove it and let the default code path handle the case.
- Fix possible failure to send a session's last few transaction commit/abort counts to the statistics collector (Tom Lane)
- Eliminate memory leaks in PL/Perl's `spi_prepare()` function (Alex Hunsaker, Tom Lane)
- Fix pg_dumpall to handle database names containing "=" correctly (Heikki Linnakangas)
- Avoid crash in pg_dump when an incorrect connection string is given (Heikki Linnakangas)
- Ignore invalid indexes in pg_dump and pg_upgrade (Michael Paquier, Bruce Momjian)

  Dumping invalid indexes can cause problems at restore time, for example if the reason the index creation failed was because it tried to enforce a uniqueness condition not satisfied by the table's data. Also, if the index creation is in fact still in progress, it seems reasonable to consider it to be an uncommitted DDL change, which pg_dump wouldn't be expected to dump anyway. pg_upgrade now also skips invalid indexes rather than failing.
- In pg_basebackup, include only the current server version's subdirectory when backing up a tablespace (Heikki Linnakangas)
- Add a server version check in pg_basebackup and pg_receivexlog, so they fail cleanly with version combinations that won't work (Heikki Linnakangas)
- Fix `contrib/dblink` to handle inconsistent settings of `DateStyle` or `IntervalStyle` safely (Daniel Farina, Tom Lane)

  Previously, if the remote server had different settings of these parameters, ambiguous dates might be read incorrectly. This fix ensures that datetime and interval columns fetched by a `dblink` query will be interpreted correctly. Note however that inconsistent settings are still risky, since literal values appearing in SQL commands sent to the remote server might be interpreted differently than they would be locally.
- Fix `contrib/pg_trgm`'s `similarity()` function to return zero for trigram-less strings (Tom Lane)

  Previously it returned `NaN` due to internal division by zero.
- Enable building PostgreSQL with Microsoft Visual Studio 2012 (Brar Piening, Noah Misch)

- Update time zone data files to tzdata release 2013b for DST law changes in Chile, Haiti, Morocco, Paraguay, and some Russian areas. Also, historical zone data corrections for numerous places.

  Also, update the time zone abbreviation files for recent changes in Russia and elsewhere: `CHOT`, `GET`, `IRKT`, `KGT`, `KRAT`, `MAGT`, `MAWT`, `MSK`, `NOVT`, `OMST`, `TKT`, `VLAT`, `WST`, `YAKT`, `YEKT` now follow their current meanings, and `VOLT` (Europe/Volgograd) and `MIST` (Antarctica/Macquarie) are added to the default abbreviations list.

E.17. Release 9.2.3

Release Date: 2013-02-07

This release contains a variety of fixes from 9.2.2. For information about new features in the 9.2 major release, see Section E.20.

E.17.1. Migration to Version 9.2.3

A dump/restore is not required for those running 9.2.X.

However, if you are upgrading from a version earlier than 9.2.2, see Section E.18.

E.17.2. Changes

- Prevent execution of `enum_recv` from SQL (Tom Lane)

  The function was misdeclared, allowing a simple SQL command to crash the server. In principle an attacker might be able to use it to examine the contents of server memory. Our thanks to Sumit Soni (via Secunia SVCRP) for reporting this issue. (CVE-2013-0255)
- Fix multiple problems in detection of when a consistent database state has been reached during WAL replay (Fujii Masao, Heikki Linnakangas, Simon Riggs, Andres Freund)
- Fix detection of end-of-backup point when no actual redo work is required (Heikki Linnakangas)

  This mistake could result in incorrect "WAL ends before end of online backup" errors.
- Update minimum recovery point when truncating a relation file (Heikki Linnakangas)

  Once data has been discarded, it's no longer safe to stop recovery at an earlier point in the timeline.
- Fix recycling of WAL segments after changing recovery target timeline (Heikki Linnakangas)
- Properly restore timeline history files from archive on cascading standby servers (Heikki Linnakangas)
- Fix lock conflict detection on hot-standby servers (Andres Freund, Robert Haas)
- Fix missing cancellations in hot standby mode (Noah Misch, Simon Riggs)

  The need to cancel conflicting hot-standby queries would sometimes be missed, allowing those queries to see inconsistent data.
- Prevent recovery pause feature from pausing before users can connect (Tom Lane)

- Fix SQL grammar to allow subscripting or field selection from a sub-SELECT result (Tom Lane)
- Fix performance problems with autovacuum truncation in busy workloads (Jan Wieck)

  Truncation of empty pages at the end of a table requires exclusive lock, but autovacuum was coded to fail (and release the table lock) when there are conflicting lock requests. Under load, it is easily possible that truncation would never occur, resulting in table bloat. Fix by performing a partial truncation, releasing the lock, then attempting to re-acquire the lock and continue. This fix also greatly reduces the average time before autovacuum releases the lock after a conflicting request arrives.
- Improve performance of `SPI_execute` and related functions, thereby improving PL/pgSQL's `EXECUTE` (Heikki Linnakangas, Tom Lane)

  Remove some data-copying overhead that was added in 9.2 as a consequence of revisions in the plan caching mechanism. This eliminates a performance regression compared to 9.1, and also saves memory, especially when the query string to be executed contains many SQL statements.

  A side benefit is that multi-statement query strings are now processed fully serially, that is we complete execution of earlier statements before running parse analysis and planning on the following ones. This eliminates a long-standing issue, in that DDL that should affect the behavior of a later statement will now behave as expected.
- Restore pre-9.2 cost estimates for index usage (Tom Lane)

  An ill-considered change of a fudge factor led to undesirably high cost estimates for use of very large indexes.
- Fix intermittent crash in `DROP INDEX CONCURRENTLY` (Tom Lane)
- Fix potential corruption of shared-memory lock table during `CREATE/DROP INDEX CONCURRENTLY` (Tom Lane)
- Fix `COPY`'s multiple-tuple-insertion code for the case of a tuple larger than page size minus fillfactor (Heikki Linnakangas)

  The previous coding could get into an infinite loop.
- Protect against race conditions when scanning `pg_tablespace` (Stephen Frost, Tom Lane)

  `CREATE DATABASE` and `DROP DATABASE` could misbehave if there were concurrent updates of `pg_tablespace` entries.
- Prevent `DROP OWNED` from trying to drop whole databases or tablespaces (Álvaro Herrera)

  For safety, ownership of these objects must be reassigned, not dropped.
- Fix error in `vacuum_freeze_table_age` implementation (Andres Freund)

  In installations that have existed for more than `vacuum_freeze_min_age` transactions, this mistake prevented autovacuum from using partial-table scans, so that a full-table scan would always happen instead.
- Prevent misbehavior when a `RowExpr` or `XmlExpr` is parse-analyzed twice (Andres Freund, Tom Lane)

  This mistake could be user-visible in contexts such as `CREATE TABLE LIKE INCLUDING INDEXES`.
- Improve defenses against integer overflow in hashtable sizing calculations (Jeff Davis)
- Fix some bugs associated with privileges on datatypes (Tom Lane)

  There were some issues with default privileges for types, and pg_dump failed to dump such privileges at all.

- Fix failure to ignore leftover temporary tables after a server crash (Tom Lane)
- Fix failure to rotate postmaster log files for size reasons on Windows (Jeff Janes, Heikki Linnakangas)
- Reject out-of-range dates in `to_date()` (Hitoshi Harada)
- Fix `pg_extension_config_dump()` to handle extension-update cases properly (Tom Lane)

  This function will now replace any existing entry for the target table, making it usable in extension update scripts.
- Fix PL/pgSQL's reporting of plan-time errors in possibly-simple expressions (Tom Lane)

  The previous coding resulted in sometimes omitting the first line in the `CONTEXT` traceback for the error.
- Fix PL/Python's handling of functions used as triggers on multiple tables (Andres Freund)
- Ensure that non-ASCII prompt strings are translated to the correct code page on Windows (Alexander Law, Noah Misch)

  This bug affected psql and some other client programs.
- Fix possible crash in psql's `\?` command when not connected to a database (Meng Qingzhong)
- Fix possible error if a relation file is removed while pg_basebackup is running (Heikki Linnakangas)
- Tolerate timeline switches while `pg_basebackup -X fetch` is backing up a standby server (Heikki Linnakangas)
- Make pg_dump exclude data of unlogged tables when running on a hot-standby server (Magnus Hagander)

  This would fail anyway because the data is not available on the standby server, so it seems most convenient to assume `--no-unlogged-table-data` automatically.
- Fix pg_upgrade to deal with invalid indexes safely (Bruce Momjian)
- Fix pg_upgrade's -O/-o options (Marti Raudsepp)
- Fix one-byte buffer overrun in libpq's `PQprintTuples` (Xi Wang)

  This ancient function is not used anywhere by PostgreSQL itself, but it might still be used by some client code.
- Make ecpglib use translated messages properly (Chen Huajun)
- Properly install ecpg_compat and pgtypes libraries on MSVC (Jiang Guiqing)
- Include our version of `isinf()` in libecpg if it's not provided by the system (Jiang Guiqing)
- Rearrange configure's tests for supplied functions so it is not fooled by bogus exports from libedit/libreadline (Christoph Berg)
- Ensure Windows build number increases over time (Magnus Hagander)
- Make pgxs build executables with the right `.exe` suffix when cross-compiling for Windows (Zoltan Boszormenyi)
- Add new timezone abbreviation `FET` (Tom Lane)

  This is now used in some eastern-European time zones.

E.18. Release 9.2.2

Release Date: 2012-12-06

This release contains a variety of fixes from 9.2.1. For information about new features in the 9.2 major release, see Section E.20.

E.18.1. Migration to Version 9.2.2

A dump/restore is not required for those running 9.2.X.

However, you may need to perform `REINDEX` operations to correct problems in concurrently-built indexes, as described in the first changelog item below.

Also, if you are upgrading from version 9.2.0, see Section E.19.

E.18.2. Changes

- Fix multiple bugs associated with `CREATE/DROP INDEX CONCURRENTLY` (Andres Freund, Tom Lane, Simon Riggs, Pavan Deolasee)

  An error introduced while adding `DROP INDEX CONCURRENTLY` allowed incorrect indexing decisions to be made during the initial phase of `CREATE INDEX CONCURRENTLY`; so that indexes built by that command could be corrupt. It is recommended that indexes built in 9.2.X with `CREATE INDEX CONCURRENTLY` be rebuilt after applying this update.

  In addition, fix `CREATE/DROP INDEX CONCURRENTLY` to use in-place updates when changing the state of an index's `pg_index` row. This prevents race conditions that could cause concurrent sessions to miss updating the target index, thus again resulting in corrupt concurrently-created indexes.

  Also, fix various other operations to ensure that they ignore invalid indexes resulting from a failed `CREATE INDEX CONCURRENTLY` command. The most important of these is `VACUUM`, because an auto-vacuum could easily be launched on the table before corrective action can be taken to fix or remove the invalid index.

  Also fix `DROP INDEX CONCURRENTLY` to not disable insertions into the target index until all queries using it are done.

  Also fix misbehavior if `DROP INDEX CONCURRENTLY` is canceled: the previous coding could leave an un-droppable index behind.

- Correct predicate locking for `DROP INDEX CONCURRENTLY` (Kevin Grittner)

  Previously, SSI predicate locks were processed at the wrong time, possibly leading to incorrect behavior of serializable transactions executing in parallel with the `DROP`.

- Fix buffer locking during WAL replay (Tom Lane)

  The WAL replay code was insufficiently careful about locking buffers when replaying WAL records that affect more than one page. This could result in hot standby queries transiently seeing inconsistent states, resulting in wrong answers or unexpected failures.

- Fix an error in WAL generation logic for GIN indexes (Tom Lane)

This could result in index corruption, if a torn-page failure occurred.

- Fix an error in WAL replay logic for SP-GiST indexes (Tom Lane)

  This could result in index corruption after a crash, or on a standby server.

- Fix incorrect detection of end-of-base-backup location during WAL recovery (Heikki Linnakangas)

  This mistake allowed hot standby mode to start up before the database reaches a consistent state.

- Properly remove startup process's virtual XID lock when promoting a hot standby server to normal running (Simon Riggs)

  This oversight could prevent subsequent execution of certain operations such as `CREATE INDEX CONCURRENTLY`.

- Avoid bogus "out-of-sequence timeline ID" errors in standby mode (Heikki Linnakangas)

- Prevent the postmaster from launching new child processes after it's received a shutdown signal (Tom Lane)

  This mistake could result in shutdown taking longer than it should, or even never completing at all without additional user action.

- Fix the syslogger process to not fail when `log_rotation_age` exceeds 2^31 milliseconds (about 25 days) (Tom Lane)

- Fix `WaitLatch()` to return promptly when the requested timeout expires (Jeff Janes, Tom Lane)

  With the previous coding, a steady stream of non-wait-terminating interrupts could delay return from `WaitLatch()` indefinitely. This has been shown to be a problem for the autovacuum launcher process, and might cause trouble elsewhere as well.

- Avoid corruption of internal hash tables when out of memory (Hitoshi Harada)

- Prevent file descriptors for dropped tables from being held open past transaction end (Tom Lane)

  This should reduce problems with long-since-dropped tables continuing to occupy disk space.

- Prevent database-wide crash and restart when a new child process is unable to create a pipe for its latch (Tom Lane)

  Although the new process must fail, there is no good reason to force a database-wide restart, so avoid that. This improves robustness when the kernel is nearly out of file descriptors.

- Avoid planner crash with joins to unflattened subqueries (Tom Lane)

- Fix planning of non-strict equivalence clauses above outer joins (Tom Lane)

  The planner could derive incorrect constraints from a clause equating a non-strict construct to something else, for example `WHERE COALESCE(foo, 0) = 0` when `foo` is coming from the nullable side of an outer join. 9.2 showed this type of error in more cases than previous releases, but the basic bug has been there for a long time.

- Fix `SELECT DISTINCT` with index-optimized `MIN`/`MAX` on an inheritance tree (Tom Lane)

  The planner would fail with "failed to re-find MinMaxAggInfo record" given this combination of factors.

- Make sure the planner sees implicit and explicit casts as equivalent for all purposes, except in the minority of cases where there's actually a semantic difference (Tom Lane)

- Include join clauses when considering whether partial indexes can be used for a query (Tom Lane)

  A strict join clause can be sufficient to establish an *x* `IS NOT NULL` predicate, for example. This fixes a planner regression in 9.2, since previous versions could make comparable deductions.

- Limit growth of planning time when there are many indexable join clauses for the same index (Tom Lane)
- Improve planner's ability to prove exclusion constraints from equivalence classes (Tom Lane)
- Fix partial-row matching in hashed subplans to handle cross-type cases correctly (Tom Lane)

  This affects multicolumn `NOT IN` subplans, such as `WHERE (a, b) NOT IN (SELECT x, y FROM ...)` when for instance `b` and `y` are `int4` and `int8` respectively. This mistake led to wrong answers or crashes depending on the specific datatypes involved.
- Fix btree mark/restore functions to handle array keys (Tom Lane)

  This oversight could result in wrong answers from merge joins whose inner side is an index scan using an *`indexed_column`* `= ANY(`*`array`*`)` condition.
- Revert patch for taking fewer snapshots (Tom Lane)

  The 9.2 change to reduce the number of snapshots taken during query execution led to some anomalous behaviors not seen in previous releases, because execution would proceed with a snapshot acquired before locking the tables used by the query. Thus, for example, a query would not be guaranteed to see updates committed by a preceding transaction even if that transaction had exclusive lock. We'll probably revisit this in future releases, but meanwhile put it back the way it was before 9.2.
- Acquire buffer lock when re-fetching the old tuple for an `AFTER ROW UPDATE/DELETE` trigger (Andres Freund)

  In very unusual circumstances, this oversight could result in passing incorrect data to a trigger `WHEN` condition, or to the precheck logic for a foreign-key enforcement trigger. That could result in a crash, or in an incorrect decision about whether to fire the trigger.
- Fix `ALTER COLUMN TYPE` to handle inherited check constraints properly (Pavan Deolasee)

  This worked correctly in pre-8.4 releases, and now works correctly in 8.4 and later.
- Fix `ALTER EXTENSION SET SCHEMA`'s failure to move some subsidiary objects into the new schema (Álvaro Herrera, Dimitri Fontaine)
- Handle `CREATE TABLE AS EXECUTE` correctly in extended query protocol (Tom Lane)
- Don't modify the input parse tree in `DROP RULE IF NOT EXISTS` and `DROP TRIGGER IF NOT EXISTS` (Tom Lane)

  This mistake would cause errors if a cached statement of one of these types was re-executed.
- Fix `REASSIGN OWNED` to handle grants on tablespaces (Álvaro Herrera)
- Ignore incorrect `pg_attribute` entries for system columns for views (Tom Lane)

  Views do not have any system columns. However, we forgot to remove such entries when converting a table to a view. That's fixed properly for 9.3 and later, but in previous branches we need to defend against existing mis-converted views.
- Fix rule printing to dump `INSERT INTO` *`table`* `DEFAULT VALUES` correctly (Tom Lane)
- Guard against stack overflow when there are too many `UNION`/`INTERSECT`/`EXCEPT` clauses in a query (Tom Lane)
- Prevent platform-dependent failures when dividing the minimum possible integer value by -1 (Xi Wang, Tom Lane)
- Fix possible access past end of string in date parsing (Hitoshi Harada)
- Fix failure to advance XID epoch if XID wraparound happens during a checkpoint and `wal_level` is `hot_standby` (Tom Lane, Andres Freund)

While this mistake had no particular impact on PostgreSQL itself, it was bad for applications that rely on `txid_current()` and related functions: the TXID value would appear to go backwards.

- Fix `pg_terminate_backend()` and `pg_cancel_backend()` to not throw error for a non-existent target process (Josh Kupershmidt)

  This case already worked as intended when called by a superuser, but not so much when called by ordinary users.

- Fix display of `pg_stat_replication.sync_state` at a page boundary (Kyotaro Horiguchi)

- Produce an understandable error message if the length of the path name for a Unix-domain socket exceeds the platform-specific limit (Tom Lane, Andrew Dunstan)

  Formerly, this would result in something quite unhelpful, such as "Non-recoverable failure in name resolution".

- Fix memory leaks when sending composite column values to the client (Tom Lane)

- Save some cycles by not searching for subtransaction locks at commit (Simon Riggs)

  In a transaction holding many exclusive locks, this useless activity could be quite costly.

- Make pg_ctl more robust about reading the `postmaster.pid` file (Heikki Linnakangas)

  This fixes race conditions and possible file descriptor leakage.

- Fix possible crash in psql if incorrectly-encoded data is presented and the `client_encoding` setting is a client-only encoding, such as SJIS (Jiang Guiqing)

- Make pg_dump dump `SEQUENCE SET` items in the data not pre-data section of the archive (Tom Lane)

  This fixes an undesirable inconsistency between the meanings of `--data-only` and `--section=data`, and also fixes dumping of sequences that are marked as extension configuration tables.

- Fix pg_dump's handling of `DROP DATABASE` commands in `--clean` mode (Guillaume Lelarge)

  Beginning in 9.2.0, `pg_dump --clean` would issue a `DROP DATABASE` command, which was either useless or dangerous depending on the usage scenario. It no longer does that. This change also fixes the combination of `--clean` and `--create` to work sensibly, i.e., emit `DROP DATABASE` then `CREATE DATABASE` before reconnecting to the target database.

- Fix pg_dump for views with circular dependencies and no relation options (Tom Lane)

  The previous fix to dump relation options when a view is involved in a circular dependency didn't work right for the case that the view has no options; it emitted `ALTER VIEW foo SET ()` which is invalid syntax.

- Fix bugs in the `restore.sql` script emitted by pg_dump in `tar` output format (Tom Lane)

  The script would fail outright on tables whose names include upper-case characters. Also, make the script capable of restoring data in `--inserts` mode as well as the regular COPY mode.

- Fix pg_restore to accept POSIX-conformant `tar` files (Brian Weaver, Tom Lane)

  The original coding of pg_dump's `tar` output mode produced files that are not fully conformant with the POSIX standard. This has been corrected for version 9.3. This patch updates previous branches so that they will accept both the incorrect and the corrected formats, in hopes of avoiding compatibility problems when 9.3 comes out.

- Fix `tar` files emitted by pg_basebackup to be POSIX conformant (Brian Weaver, Tom Lane)

- Fix pg_resetxlog to locate `postmaster.pid` correctly when given a relative path to the data directory (Tom Lane)

This mistake could lead to pg_resetxlog not noticing that there is an active postmaster using the data directory.

- Fix libpq's `lo_import()` and `lo_export()` functions to report file I/O errors properly (Tom Lane)
- Fix ecpg's processing of nested structure pointer variables (Muhammad Usama)
- Fix ecpg's `ecpg_get_data` function to handle arrays properly (Michael Meskes)
- Prevent pg_upgrade from trying to process TOAST tables for system catalogs (Bruce Momjian)

  This fixes an error seen when the `information_schema` has been dropped and recreated. Other failures were also possible.
- Improve pg_upgrade performance by setting `synchronous_commit` to `off` in the new cluster (Bruce Momjian)
- Make `contrib/pageinspect`'s btree page inspection functions take buffer locks while examining pages (Tom Lane)
- Work around unportable behavior of `malloc(0)` and `realloc(NULL, 0)` (Tom Lane)

  On platforms where these calls return `NULL`, some code mistakenly thought that meant out-of-memory. This is known to have broken pg_dump for databases containing no user-defined aggregates. There might be other cases as well.
- Ensure that `make install` for an extension creates the `extension` installation directory (Cédric Villemain)

  Previously, this step was missed if `MODULEDIR` was set in the extension's Makefile.
- Fix pgxs support for building loadable modules on AIX (Tom Lane)

  Building modules outside the original source tree didn't work on AIX.
- Update time zone data files to tzdata release 2012j for DST law changes in Cuba, Israel, Jordan, Libya, Palestine, Western Samoa, and portions of Brazil.

E.19. Release 9.2.1

Release Date: 2012-09-24

This release contains a variety of fixes from 9.2.0. For information about new features in the 9.2 major release, see Section E.20.

E.19.1. Migration to Version 9.2.1

A dump/restore is not required for those running 9.2.X.

However, you may need to perform `REINDEX` and/or `VACUUM` operations to recover from the effects of the data corruption bug described in the first changelog item below.

E.19.2. Changes

- Fix persistence marking of shared buffers during WAL replay (Jeff Davis)

  This mistake can result in buffers not being written out during checkpoints, resulting in data corruption if the server later crashes without ever having written those buffers. Corruption can occur on any server following crash recovery, but it is significantly more likely to occur on standby slave servers since those perform much more WAL replay. There is a low probability of corruption of btree and GIN indexes. There is a much higher probability of corruption of table "visibility maps", which might lead to wrong answers from index-only scans. Table data proper cannot be corrupted by this bug.

  While no index corruption due to this bug is known to have occurred in the field, as a precautionary measure it is recommended that production installations `REINDEX` all btree and GIN indexes at a convenient time after upgrading to 9.2.1.

  Also, it is recommended to perform a `VACUUM` of all tables while having `vacuum_freeze_table_age` set to zero. This will fix any incorrect visibility map data. `vacuum_cost_delay` can be adjusted to reduce the performance impact of vacuuming, while causing it to take longer to finish.

- Fix possible incorrect sorting of output from queries involving `WHERE` *`indexed_column`* `IN (`*`list_of_values`*`)` (Tom Lane)

- Fix planner failure for queries involving `GROUP BY` expressions along with window functions and aggregates (Tom Lane)

- Fix planner's assignment of executor parameters (Tom Lane)

  This error could result in wrong answers from queries that scan the same `WITH` subquery multiple times.

- Improve planner's handling of join conditions in index scans (Tom Lane)

- Improve selectivity estimation for text search queries involving prefixes, i.e. *`word`*`:*` patterns (Tom Lane)

- Fix delayed recognition of permissions changes (Tom Lane)

  A command that needed no locks other than ones its transaction already had might fail to notice a concurrent `GRANT` or `REVOKE` that committed since the start of its transaction.

- Fix `ANALYZE` to not fail when a column is a domain over an array type (Tom Lane)

- Prevent PL/Perl from crashing if a recursive PL/Perl function is redefined while being executed (Tom Lane)

- Work around possible misoptimization in PL/Perl (Tom Lane)

  Some Linux distributions contain an incorrect version of `pthread.h` that results in incorrect compiled code in PL/Perl, leading to crashes if a PL/Perl function calls another one that throws an error.

- Remove unnecessary dependency on pg_config from pg_upgrade (Peter Eisentraut)

- Update time zone data files to tzdata release 2012f for DST law changes in Fiji

E.20. Release 9.2

Release Date: 2012-09-10

E.20.1. Overview

This release has been largely focused on performance improvements, though new SQL features are not lacking. Work also continues in the area of replication support. Major enhancements include:

- Allow queries to retrieve data only from indexes, avoiding heap access (*index-only scans*)
- Allow the planner to generate custom plans for specific parameter values even when using prepared statements
- Improve the planner's ability to use nested loops with inner index scans
- Allow streaming replication slaves to forward data to other slaves (*cascading replication*)
- Allow pg_basebackup to make base backups from standby servers
- Add a pg_receivexlog tool to archive WAL file changes as they are written
- Add the SP-GiST (Space-Partitioned GiST) index access method
- Add support for range data types
- Add a `JSON` data type
- Add a `security_barrier` option for views
- Allow libpq connection strings to have the format of a URI
- Add a single-row processing mode to libpq for better handling of large result sets

The above items are explained in more detail in the sections below.

E.20.2. Migration to Version 9.2

A dump/restore using pg_dump, or use of pg_upgrade, is required for those wishing to migrate data from any previous release.

Version 9.2 contains a number of changes that may affect compatibility with previous releases. Observe the following incompatibilities:

E.20.2.1. System Catalogs

- Remove the `spclocation` field from `pg_tablespace` (Magnus Hagander)

  This field was duplicative of the symbolic links that actually define tablespace locations, and thus risked errors of omission when moving a tablespace. This change allows tablespace directories to be moved while the server is down, by manually adjusting the symbolic links. To replace this field, we have added `pg_tablespace_location()` to allow querying of the symbolic links.
- Move `tsvector` most-common-element statistics to new `pg_stats` columns (Alexander Korotkov)

Consult `most_common_elems` and `most_common_elem_freqs` for the data formerly available in `most_common_vals` and `most_common_freqs` for a `tsvector` column.

E.20.2.2. Functions

- Remove hstore's => operator (Robert Haas)

  Users should now use `hstore(text, text)`. Since PostgreSQL 9.0, a warning message has been emitted when an operator named => is created because the SQL standard reserves that token for another use.

- Ensure that `xpath()` escapes special characters in string values (Florian Pflug)

  Without this it is possible for the result not to be valid XML.

- Make `pg_relation_size()` and friends return NULL if the object does not exist (Phil Sorber)

  This prevents queries that call these functions from returning errors immediately after a concurrent `DROP`.

- Make `EXTRACT(EPOCH FROM` *`timestamp without time zone`*`)` measure the epoch from local midnight, not UTC midnight (Tom Lane)

  This change reverts an ill-considered change made in release 7.3. Measuring from UTC midnight was inconsistent because it made the result dependent on the `timezone` setting, which computations for `timestamp without time zone` should not be. The previous behavior remains available by casting the input value to `timestamp with time zone`.

- Properly parse time strings with trailing `yesterday`, `today`, and `tomorrow` (Dean Rasheed)

  Previously, `SELECT '04:00:00 yesterday'::timestamp` returned yesterday's date at midnight.

- Fix `to_date()` and `to_timestamp()` to wrap incomplete dates toward 2020 (Bruce Momjian)

  Previously, supplied years and year masks of less than four digits wrapped inconsistently.

E.20.2.3. Object Modification

- Prevent `ALTER DOMAIN` from working on non-domain types (Peter Eisentraut)

  Owner and schema changes were previously possible on non-domain types.

- No longer forcibly lowercase procedural language names in `CREATE FUNCTION` (Robert Haas)

  While unquoted language identifiers are still lowercased, strings and quoted identifiers are no longer forcibly down-cased. Thus for example `CREATE FUNCTION ... LANGUAGE 'C'` will no longer work; it must be spelled `'c'`, or better omit the quotes.

- Change system-generated names of foreign key enforcement triggers (Tom Lane)

  This change ensures that the triggers fire in the correct order in some corner cases involving self-referential foreign key constraints.

E.20.2.4. Command-Line Tools

- Provide consistent backquote, variable expansion, and quoted substring behavior in psql meta-command arguments (Tom Lane)

  Previously, such references were treated oddly when not separated by whitespace from adjacent text. For example `'FOO'BAR` was output as `FOO BAR` (unexpected insertion of a space) and `FOO'BAR'BAZ` was output unchanged (not removing the quotes as most would expect).

- No longer treat clusterdb table names as double-quoted; no longer treat reindexdb table and index names as double-quoted (Bruce Momjian)

  Users must now include double-quotes in the command arguments if quoting is wanted.

- createuser no longer prompts for option settings by default (Peter Eisentraut)

  Use `--interactive` to obtain the old behavior.

- Disable prompting for the user name in dropuser unless `--interactive` is specified (Peter Eisentraut)

E.20.2.5. Server Settings

- Add server parameters for specifying the locations of server-side SSL files (Peter Eisentraut)

  This allows changing the names and locations of the files that were previously hard-coded as `server.crt`, `server.key`, `root.crt`, and `root.crl` in the data directory. *The server will no longer examine `root.crt` or `root.crl` by default*; to load these files, the associated parameters must be set to non-default values.

- Remove the `silent_mode` parameter (Heikki Linnakangas)

  Similar behavior can be obtained with `pg_ctl start -l postmaster.log`.

- Remove the `wal_sender_delay` parameter, as it is no longer needed (Tom Lane)

- Remove the `custom_variable_classes` parameter (Tom Lane)

  The checking provided by this setting was dubious. Now any setting can be prefixed by any class name.

E.20.2.6. Monitoring

- Rename `pg_stat_activity.procpid` to `pid`, to match other system tables (Magnus Hagander)

- Create a separate `pg_stat_activity` column to report process state (Scott Mead, Magnus Hagander)

  The previous `query` and `query_start` values now remain available for an idle session, allowing enhanced analysis.

- Rename `pg_stat_activity.current_query` to `query` because it is not cleared when the query completes (Magnus Hagander)

- Change all SQL-level statistics timing values to be `float8` columns measured in milliseconds (Tom Lane)

  This change eliminates the designed-in assumption that the values are accurate to microseconds and no more (since the `float8` values can be fractional).

The columns affected are `pg_stat_user_functions.total_time`, `pg_stat_user_functions.self_time`, `pg_stat_xact_user_functions.total_time`, and `pg_stat_xact_user_functions.self_time`. The statistics functions underlying these columns now also return `float8` milliseconds, rather than `bigint` microseconds. `contrib/pg_stat_statements`' `total_time` column is now also measured in milliseconds.

E.20.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 9.2 and the previous major release.

E.20.3.1. Server

E.20.3.1.1. Performance

- Allow queries to retrieve data only from indexes, avoiding heap access (Robert Haas, Ibrar Ahmed, Heikki Linnakangas, Tom Lane)

  This feature is often called *index-only scans*. Heap access can be skipped for heap pages containing only tuples that are visible to all sessions, as reported by the visibility map; so the benefit applies mainly to mostly-static data. The visibility map was made crash-safe as a necessary part of implementing this feature.

- Add the SP-GiST (Space-Partitioned GiST) index access method (Teodor Sigaev, Oleg Bartunov, Tom Lane)

  SP-GiST is comparable to GiST in flexibility, but supports unbalanced partitioned search structures rather than balanced trees. For suitable problems, SP-GiST can be faster than GiST in both index build time and search time.

- Allow group commit to work effectively under heavy load (Peter Geoghegan, Simon Riggs, Heikki Linnakangas)

  Previously, batching of commits became ineffective as the write workload increased, because of internal lock contention.

- Allow uncontended locks to be managed using a new fast-path lock mechanism (Robert Haas)
- Reduce overhead of creating virtual transaction ID locks (Robert Haas)
- Reduce the overhead of serializable isolation level locks (Dan Ports)
- Improve PowerPC and Itanium spinlock performance (Manabu Ori, Robert Haas, Tom Lane)
- Reduce overhead for shared invalidation cache messages (Robert Haas)
- Move the frequently accessed members of the `PGPROC` shared memory array to a separate array (Pavan Deolasee, Heikki Linnakangas, Robert Haas)
- Improve `COPY` performance by adding tuples to the heap in batches (Heikki Linnakangas)
- Improve GiST index performance for geometric data types by producing better trees with less memory allocation overhead (Alexander Korotkov)
- Improve GiST index build times (Alexander Korotkov, Heikki Linnakangas)
- Allow hint bits to be set sooner for temporary and unlogged tables (Robert Haas)

- Allow sorting to be performed by inlined, non-SQL-callable comparison functions (Peter Geoghegan, Robert Haas, Tom Lane)
- Make the number of CLOG buffers scale based on `shared_buffers` (Robert Haas, Simon Riggs, Tom Lane)
- Improve performance of buffer pool scans that occur when tables or databases are dropped (Jeff Janes, Simon Riggs)
- Improve performance of checkpointer's fsync-request queue when many tables are being dropped or truncated (Tom Lane)
- Pass the safe number of file descriptors to child processes on Windows (Heikki Linnakangas)

  This allows Windows sessions to use more open file descriptors than before.

E.20.3.1.2. Process Management

- Create a dedicated background process to perform checkpoints (Simon Riggs)

  Formerly the background writer did both dirty-page writing and checkpointing. Separating this into two processes allows each goal to be accomplished more predictably.
- Improve asynchronous commit behavior by waking the walwriter sooner (Simon Riggs)

  Previously, only `wal_writer_delay` triggered WAL flushing to disk; now filling a WAL buffer also triggers WAL writes.
- Allow the bgwriter, walwriter, checkpointer, statistics collector, log collector, and archiver background processes to sleep more efficiently during periods of inactivity (Peter Geoghegan, Tom Lane)

  This series of changes reduces the frequency of process wake-ups when there is nothing to do, dramatically reducing power consumption on idle servers.

E.20.3.1.3. Optimizer

- Allow the planner to generate custom plans for specific parameter values even when using prepared statements (Tom Lane)

  In the past, a prepared statement always had a single "generic" plan that was used for all parameter values, which was frequently much inferior to the plans used for non-prepared statements containing explicit constant values. Now, the planner attempts to generate custom plans for specific parameter values. A generic plan will only be used after custom plans have repeatedly proven to provide no benefit. This change should eliminate the performance penalties formerly seen from use of prepared statements (including non-dynamic statements in PL/pgSQL).
- Improve the planner's ability to use nested loops with inner index scans (Tom Lane)

  The new "parameterized path" mechanism allows inner index scans to use values from relations that are more than one join level up from the scan. This can greatly improve performance in situations where semantic restrictions (such as outer joins) limit the allowed join orderings.
- Improve the planning API for foreign data wrappers (Etsuro Fujita, Shigeru Hanada, Tom Lane)

  Wrappers can now provide multiple access "paths" for their tables, allowing more flexibility in join planning.
- Recognize self-contradictory restriction clauses for non-table relations (Tom Lane)

This check is only performed when `constraint_exclusion` is `on`.

- Allow `indexed_col op ANY(ARRAY[...])` conditions to be used in plain index scans and index-only scans (Tom Lane)

  Formerly such conditions could only be used in bitmap index scans.

- Support `MIN`/`MAX` index optimizations on `boolean` columns (Marti Raudsepp)
- Account for set-returning functions in `SELECT` target lists when setting row count estimates (Tom Lane)
- Fix planner to handle indexes with duplicated columns more reliably (Tom Lane)
- Collect and use element-frequency statistics for arrays (Alexander Korotkov, Tom Lane)

  This change improves selectivity estimation for the array `<@`, `&&`, and `@>` operators (array containment and overlaps).

- Allow statistics to be collected for foreign tables (Etsuro Fujita)
- Improve cost estimates for use of partial indexes (Tom Lane)
- Improve the planner's ability to use statistics for columns referenced in subqueries (Tom Lane)
- Improve statistical estimates for subqueries using `DISTINCT` (Tom Lane)

E.20.3.1.4. Authentication

- Do not treat role names and `samerole` specified in `pg_hba.conf` as automatically including superusers (Andrew Dunstan)

  This makes it easier to use `reject` lines with group roles.

- Adjust `pg_hba.conf` processing to handle token parsing more consistently (Brendan Jurd, Álvaro Herrera)
- Disallow empty `pg_hba.conf` files (Tom Lane)

  This was done to more quickly detect misconfiguration.

- Make superuser privilege imply replication privilege (Noah Misch)

  This avoids the need to explicitly assign such privileges.

E.20.3.1.5. Monitoring

- Attempt to log the current query string during a backend crash (Marti Raudsepp)
- Make logging of autovacuum I/O activity more verbose (Greg Smith, Noah Misch)

  This logging is triggered by `log_autovacuum_min_duration`.

- Make WAL replay report failures sooner (Fujii Masao)

  There were some cases where failures were only reported once the server went into master mode.

- Add `pg_xlog_location_diff()` to simplify WAL location comparisons (Euler Taveira de Oliveira)

  This is useful for computing replication lag.

- Support configurable event log application names on Windows (MauMau, Magnus Hagander)

This allows different instances to use the event log with different identifiers, by setting the `event_source` server parameter, which is similar to how `syslog_ident` works.

- Change "unexpected EOF" messages to `DEBUG1` level, except when there is an open transaction (Magnus Hagander)

  This change reduces log chatter caused by applications that close database connections ungracefully.

E.20.3.1.6. Statistical Views

- Track temporary file sizes and file counts in the `pg_stat_database` system view (Tomas Vondra)
- Add a deadlock counter to the `pg_stat_database` system view (Magnus Hagander)
- Add a server parameter `track_io_timing` to track I/O timings (Ants Aasma, Robert Haas)
- Report checkpoint timing information in `pg_stat_bgwriter` (Greg Smith, Peter Geoghegan)

E.20.3.1.7. Server Settings

- Silently ignore nonexistent schemas specified in `search_path` (Tom Lane)

  This makes it more convenient to use generic path settings, which might include some schemas that don't exist in all databases.

- Allow superusers to set `deadlock_timeout` per-session, not just per-cluster (Noah Misch)

  This allows `deadlock_timeout` to be reduced for transactions that are likely to be involved in a deadlock, thus detecting the failure more quickly. Alternatively, increasing the value can be used to reduce the chances of a session being chosen for cancellation due to a deadlock.

- Add a server parameter `temp_file_limit` to constrain temporary file space usage per session (Mark Kirkwood)
- Allow a superuser to `SET` an extension's superuser-only custom variable before loading the associated extension (Tom Lane)

  The system now remembers whether a `SET` was performed by a superuser, so that proper privilege checking can be done when the extension is loaded.

- Add postmaster `-C` option to query configuration parameters (Bruce Momjian)

  This allows pg_ctl to better handle cases where `PGDATA` or `-D` points to a configuration-only directory.

- Replace an empty locale name with the implied value in `CREATE DATABASE` (Tom Lane)

  This prevents cases where `pg_database.datcollate` or `datctype` could be interpreted differently after a server restart.

E.20.3.1.7.1. *postgresql.conf*

- Allow multiple errors in `postgresql.conf` to be reported, rather than just the first one (Alexey Klyukin, Tom Lane)
- Allow a reload of `postgresql.conf` to be processed by all sessions, even if there are some settings that are invalid for particular sessions (Alexey Klyukin)

Previously, such not-valid-within-session values would cause all setting changes to be ignored by that session.

- Add an `include_if_exists` facility for configuration files (Greg Smith)

  This works the same as `include`, except that an error is not thrown if the file is missing.

- Identify the server time zone during initdb, and set `postgresql.conf` entries `timezone` and `log_timezone` accordingly (Tom Lane)

  This avoids expensive time zone probes during server start.

- Fix `pg_settings` to report `postgresql.conf` line numbers on Windows (Tom Lane)

E.20.3.2. Replication and Recovery

- Allow streaming replication slaves to forward data to other slaves (*cascading replication*) (Fujii Masao)

  Previously, only the master server could supply streaming replication log files to standby servers.

- Add new `synchronous_commit` mode `remote_write` (Fujii Masao, Simon Riggs)

  This mode waits for the standby server to write transaction data to its own operating system, but does not wait for the data to be flushed to the standby's disk.

- Add a pg_receivexlog tool to archive WAL file changes as they are written, rather than waiting for completed WAL files (Magnus Hagander)

- Allow pg_basebackup to make base backups from standby servers (Jun Ishizuka, Fujii Masao)

  This feature lets the work of making new base backups be off-loaded from the primary server.

- Allow streaming of WAL files while pg_basebackup is performing a backup (Magnus Hagander)

  This allows passing of WAL files to the standby before they are discarded on the primary.

E.20.3.3. Queries

- Cancel the running query if the client gets disconnected (Florian Pflug)

  If the backend detects loss of client connection during a query, it will now cancel the query rather than attempting to finish it.

- Retain column names at run time for row expressions (Andrew Dunstan, Tom Lane)

  This change allows better results when a row value is converted to `hstore` or `json` type: the fields of the resulting value will now have the expected names.

- Improve column labels used for sub-`SELECT` results (Marti Raudsepp)

  Previously, the generic label `?column?` was used.

- Improve heuristics for determining the types of unknown values (Tom Lane)

  The longstanding rule that an unknown constant might have the same type as the value on the other side of the operator using it is now applied when considering polymorphic operators, not only for simple operator matches.

- Warn about creating casts to or from domain types (Robert Haas)

Such casts have no effect.

- When a row fails a CHECK or NOT NULL constraint, show the row's contents as error detail (Jan Kundrát)

  This should make it easier to identify which row is problematic when an insert or update is processing many rows.

E.20.3.4. Object Manipulation

- Provide more reliable operation during concurrent DDL (Robert Haas, Noah Misch)

  This change adds locking that should eliminate "cache lookup failed" errors in many scenarios. Also, it is no longer possible to add relations to a schema that is being concurrently dropped, a scenario that formerly led to inconsistent system catalog contents.

- Add CONCURRENTLY option to DROP INDEX (Simon Riggs)

  This allows index removal without blocking other sessions.

- Allow foreign data wrappers to have per-column options (Shigeru Hanada)

- Improve pretty-printing of view definitions (Andrew Dunstan)

E.20.3.4.1. Constraints

- Allow CHECK constraints to be declared NOT VALID (Álvaro Herrera)

  Adding a NOT VALID constraint does not cause the table to be scanned to verify that existing rows meet the constraint. Subsequently, newly added or updated rows are checked. Such constraints are ignored by the planner when considering constraint_exclusion, since it is not certain that all rows meet the constraint.

  The new ALTER TABLE VALIDATE command allows NOT VALID constraints to be checked for existing rows, after which they are converted into ordinary constraints.

- Allow CHECK constraints to be declared NO INHERIT (Nikhil Sontakke, Alex Hunsaker, Álvaro Herrera)

  This makes them enforceable only on the parent table, not on child tables.

- Add the ability to rename constraints (Peter Eisentraut)

E.20.3.4.2. ALTER

- Reduce need to rebuild tables and indexes for certain ALTER TABLE ... ALTER COLUMN TYPE operations (Noah Misch)

  Increasing the length limit for a varchar or varbit column, or removing the limit altogether, no longer requires a table rewrite. Similarly, increasing the allowable precision of a numeric column, or changing a column from constrained numeric to unconstrained numeric, no longer requires a table rewrite. Table rewrites are also avoided in similar cases involving the interval, timestamp, and timestamptz types.

- Avoid having ALTER TABLE revalidate foreign key constraints in some cases where it is not necessary (Noah Misch)

- Add IF EXISTS options to some ALTER commands (Pavel Stehule)

For example, `ALTER FOREIGN TABLE IF EXISTS foo RENAME TO bar`.

- Add `ALTER FOREIGN DATA WRAPPER ... RENAME` and `ALTER SERVER ... RENAME` (Peter Eisentraut)
- Add `ALTER DOMAIN ... RENAME` (Peter Eisentraut)

  You could already rename domains using `ALTER TYPE`.
- Throw an error for `ALTER DOMAIN ... DROP CONSTRAINT` on a nonexistent constraint (Peter Eisentraut)

  An `IF EXISTS` option has been added to provide the previous behavior.

E.20.3.4.3. `CREATE TABLE`

- Allow `CREATE TABLE (LIKE ...)` from foreign tables, views, and composite types (Peter Eisentraut)

  For example, this allows a table to be created whose schema matches a view.
- Fix `CREATE TABLE (LIKE ...)` to avoid index name conflicts when copying index comments (Tom Lane)
- Fix `CREATE TABLE ... AS EXECUTE` to handle `WITH NO DATA` and column name specifications (Tom Lane)

E.20.3.4.4. Object Permissions

- Add a `security_barrier` option for views (KaiGai Kohei, Robert Haas)

  This option prevents optimizations that might allow view-protected data to be exposed to users, for example pushing a clause involving an insecure function into the `WHERE` clause of the view. Such views can be expected to perform more poorly than ordinary views.
- Add a new `LEAKPROOF` function attribute to mark functions that can safely be pushed down into `security_barrier` views (KaiGai Kohei)
- Add support for privileges on data types (Peter Eisentraut)

  This adds support for the SQL-conforming `USAGE` privilege on types and domains. The intent is to be able to restrict which users can create dependencies on types, since such dependencies limit the owner's ability to alter the type.
- Check for `INSERT` privileges in `SELECT INTO` / `CREATE TABLE AS` (KaiGai Kohei)

  Because the object is being created by `SELECT INTO` or `CREATE TABLE AS`, the creator would ordinarily have insert permissions; but there are corner cases where this is not true, such as when `ALTER DEFAULT PRIVILEGES` has removed such permissions.

E.20.3.5. Utility Operations

- Allow `VACUUM` to more easily skip pages that cannot be locked (Simon Riggs, Robert Haas)

  This change should greatly reduce the incidence of `VACUUM` getting "stuck" waiting for other sessions.

- Make `EXPLAIN (BUFFERS)` count blocks dirtied and written (Robert Haas)
- Make `EXPLAIN ANALYZE` report the number of rows rejected by filter steps (Marko Tiikkaja)
- Allow `EXPLAIN ANALYZE` to avoid timing overhead when time values are not wanted (Tomas Vondra)

  This is accomplished by setting the new `TIMING` option to `FALSE`.

E.20.3.6. Data Types

- Add support for range data types (Jeff Davis, Tom Lane, Alexander Korotkov)

  A range data type stores a lower and upper bound belonging to its base data type. It supports operations like contains, overlaps, and intersection.
- Add a `JSON` data type (Robert Haas)

  This type stores JSON (JavaScript Object Notation) data with proper validation.
- Add `array_to_json()` and `row_to_json()` (Andrew Dunstan)
- Add a `SMALLSERIAL` data type (Mike Pultz)

  This is like `SERIAL`, except it stores the sequence in a two-byte integer column (`int2`).
- Allow domains to be declared `NOT VALID` (Álvaro Herrera)

  This option can be set at domain creation time, or via `ALTER DOMAIN ... ADD CONSTRAINT ... NOT VALID`. `ALTER DOMAIN ... VALIDATE CONSTRAINT` fully validates the constraint.
- Support more locale-specific formatting options for the `money` data type (Tom Lane)

  Specifically, honor all the POSIX options for ordering of the value, sign, and currency symbol in monetary output. Also, make sure that the thousands separator is only inserted to the left of the decimal point, as required by POSIX.
- Add bitwise "and", "or", and "not" operators for the `macaddr` data type (Brendan Jurd)
- Allow `xpath()` to return a single-element XML array when supplied a scalar value (Florian Pflug)

  Previously, it returned an empty array. This change will also cause `xpath_exists()` to return true, not false, for such expressions.
- Improve XML error handling to be more robust (Florian Pflug)

E.20.3.7. Functions

- Allow non-superusers to use `pg_cancel_backend()` and `pg_terminate_backend()` on other sessions belonging to the same user (Magnus Hagander, Josh Kupershmidt, Dan Farina)

  Previously only superusers were allowed to use these functions.
- Allow importing and exporting of transaction snapshots (Joachim Wieland, Tom Lane)

  This allows multiple transactions to share identical views of the database state. Snapshots are exported via `pg_export_snapshot()` and imported via `SET TRANSACTION SNAPSHOT`. Only snapshots from currently-running transactions can be imported.
- Support `COLLATION FOR` on expressions (Peter Eisentraut)

  This returns a string representing the collation of the expression.

- Add `pg_opfamily_is_visible()` (Josh Kupershmidt)
- Add a `numeric` variant of `pg_size_pretty()` for use with `pg_xlog_location_diff()` (Fujii Masao)
- Add a `pg_trigger_depth()` function (Kevin Grittner)

  This reports the current trigger call depth.
- Allow `string_agg()` to process `bytea` values (Pavel Stehule)
- Fix regular expressions in which a back-reference occurs within a larger quantified subexpression (Tom Lane)

  For example, `^(\w+)( \1)+$`. Previous releases did not check that the back-reference actually matched the first occurrence.

E.20.3.8. Information Schema

- Add information schema views `role_udt_grants`, `udt_privileges`, and `user_defined_types` (Peter Eisentraut)
- Add composite-type attributes to the information schema `element_types` view (Peter Eisentraut)
- Implement `interval_type` columns in the information schema (Peter Eisentraut)

  Formerly these columns read as nulls.
- Implement collation-related columns in the information schema `attributes`, `columns`, `domains`, and `element_types` views (Peter Eisentraut)
- Implement the `with_hierarchy` column in the information schema `table_privileges` view (Peter Eisentraut)
- Add display of sequence `USAGE` privileges to information schema (Peter Eisentraut)
- Make the information schema show default privileges (Peter Eisentraut)

  Previously, non-empty default permissions were not represented in the views.

E.20.3.9. Server-Side Languages

E.20.3.9.1. PL/pgSQL Server-Side Language

- Allow the PL/pgSQL `OPEN` cursor command to supply parameters by name (Yeb Havinga)
- Add a `GET STACKED DIAGNOSTICS` PL/pgSQL command to retrieve exception info (Pavel Stehule)
- Speed up PL/pgSQL array assignment by caching type information (Pavel Stehule)
- Improve performance and memory consumption for long chains of `ELSIF` clauses (Tom Lane)
- Output the function signature, not just the name, in PL/pgSQL error messages (Pavel Stehule)

E.20.3.9.2. PL/Python Server-Side Language

- Add PL/Python SPI cursor support (Jan Urbanski)

This allows PL/Python to read partial result sets.

- Add result metadata functions to PL/Python (Peter Eisentraut)

  Specifically, this adds result object functions `.colnames`, `.coltypes`, and `.coltypmods`.

- Remove support for Python 2.2 (Peter Eisentraut)

E.20.3.9.3. SQL Server-Side Language

- Allow SQL-language functions to reference parameters by name (Matthew Draper)

  To use this, simply name the function arguments and then reference the argument names in the SQL function body.

E.20.3.10. Client Applications

- Add initdb options `--auth-local` and `--auth-host` (Peter Eisentraut)

  This allows separate control of `local` and `host` `pg_hba.conf` authentication settings. `--auth` still controls both.

- Add `--replication`/`--no-replication` flags to createuser to control replication permission (Fujii Masao)
- Add the `--if-exists` option to dropdb and dropuser (Josh Kupershmidt)
- Give command-line tools the ability to specify the name of the database to connect to, and fall back to `template1` if a `postgres` database connection fails (Robert Haas)

E.20.3.10.1. psql

- Add a display mode to auto-expand output based on the display width (Peter Eisentraut)

  This adds the `auto` option to the `\x` command, which switches to the expanded mode when the normal output would be wider than the screen.

- Allow inclusion of a script file that is named relative to the directory of the file from which it was invoked (Gurjeet Singh)

  This is done with a new command `\ir`.

- Add support for non-ASCII characters in psql variable names (Tom Lane)
- Add support for major-version-specific `.psqlrc` files (Bruce Momjian)

  psql already supported minor-version-specific `.psqlrc` files.

- Provide environment variable overrides for psql history and startup file locations (Andrew Dunstan)

  `PSQL_HISTORY` and `PSQLRC` now determine these file names if set.

- Add a `\setenv` command to modify the environment variables passed to child processes (Andrew Dunstan)
- Name psql's temporary editor files with a `.sql` extension (Peter Eisentraut)

  This allows extension-sensitive editors to select the right mode.

- Allow psql to use zero-byte field and record separators (Peter Eisentraut)

Various shell tools use zero-byte (NUL) separators, e.g. find.

- Make the `\timing` option report times for failed queries (Magnus Hagander)

  Previously times were reported only for successful queries.

- Unify and tighten psql's treatment of `\copy` and SQL `COPY` (Noah Misch)

  This fix makes failure behavior more predictable and honors `\set ON_ERROR_ROLLBACK`.

E.20.3.10.2. Informational Commands

- Make `\d` on a sequence show the table/column name owning it (Magnus Hagander)
- Show statistics target for columns in `\d+` (Magnus Hagander)
- Show role password expiration dates in `\du` (Fabrízio de Royes Mello)
- Display comments for casts, conversions, domains, and languages (Josh Kupershmidt)

  These are included in the output of `\dC+`, `\dc+`, `\dD+`, and `\dL` respectively.

- Display comments for SQL/MED objects (Josh Kupershmidt)

  These are included in the output of `\des+`, `\det+`, and `\dew+` for foreign servers, foreign tables, and foreign data wrappers respectively.

- Change `\dd` to display comments only for object types without their own backslash command (Josh Kupershmidt)

E.20.3.10.3. Tab Completion

- In psql tab completion, complete SQL keywords in either upper or lower case according to the new `COMP_KEYWORD_CASE` setting (Peter Eisentraut)
- Add tab completion support for `EXECUTE` (Andreas Karlsson)
- Allow tab completion of role references in `GRANT`/`REVOKE` (Peter Eisentraut)
- Allow tab completion of file names to supply quotes, when necessary (Noah Misch)
- Change tab completion support for `TABLE` to also include views (Magnus Hagander)

E.20.3.10.4. pg_dump

- Add an `--exclude-table-data` option to pg_dump (Andrew Dunstan)

  This allows dumping of a table's definition but not its data, on a per-table basis.

- Add a `--section` option to pg_dump and pg_restore (Andrew Dunstan)

  Valid values are `pre-data`, `data`, and `post-data`. The option can be given more than once to select two or more sections.

- Make pg_dumpall dump all roles first, then all configuration settings on roles (Phil Sorber)

  This allows a role's configuration settings to mention other roles without generating an error.

- Allow pg_dumpall to avoid errors if the `postgres` database is missing in the new cluster (Robert Haas)
- Dump foreign server user mappings in user name order (Peter Eisentraut)

This helps produce deterministic dump files.

- Dump operators in a predictable order (Peter Eisentraut)
- Tighten rules for when extension configuration tables are dumped by pg_dump (Tom Lane)
- Make pg_dump emit more useful dependency information (Tom Lane)

  The dependency links included in archive-format dumps were formerly of very limited use, because they frequently referenced objects that appeared nowhere in the dump. Now they represent actual dependencies (possibly indirect) among the dumped objects.
- Improve pg_dump's performance when dumping many database objects (Tom Lane)

E.20.3.11. libpq

- Allow libpq connection strings to have the format of a URI (Alexander Shulgin)

  The syntax begins with `postgres://`. This can allow applications to avoid implementing their own parser for URIs representing database connections.
- Add a connection option to disable SSL compression (Laurenz Albe)

  This can be used to remove the overhead of SSL compression on fast networks.
- Add a single-row processing mode for better handling of large result sets (Kyotaro Horiguchi, Marko Kreen)

  Previously, libpq always collected the entire query result in memory before passing it back to the application.
- Add `const` qualifiers to the declarations of the functions `PQconnectdbParams`, `PQconnectStartParams`, and `PQpingParams` (Lionel Elie Mamane)
- Allow the `.pgpass` file to include escaped characters in the password field (Robert Haas)
- Make library functions use `abort()` instead of `exit()` when it is necessary to terminate the process (Peter Eisentraut)

  This choice does not interfere with the normal exit codes used by the program, and generates a signal that can be caught by the caller.

E.20.3.12. Source Code

- Remove dead ports (Peter Eisentraut)

  The following platforms are no longer supported: dgux, nextstep, sunos4, svr4, ultrix4, univel, bsdi.
- Add support for building with MS Visual Studio 2010 (Brar Piening)
- Enable compiling with the MinGW-w64 32-bit compiler (Lars Kanis)
- Install `plpgsql.h` into `include/server` during installation (Heikki Linnakangas)
- Improve the latch facility to include detection of postmaster death (Peter Geoghegan, Heikki Linnakangas, Tom Lane)

  This eliminates one of the main reasons that background processes formerly had to wake up to poll for events.
- Use C flexible array members, where supported (Peter Eisentraut)

- Improve the concurrent transaction regression tests (isolationtester) (Noah Misch)
- Modify thread_test to create its test files in the current directory, rather than `/tmp` (Bruce Momjian)
- Improve flex and bison warning and error reporting (Tom Lane)
- Add memory barrier support (Robert Haas)

  This is currently unused.
- Modify pgindent to use a typedef file (Bruce Momjian)
- Add a hook for processing messages due to be sent to the server log (Martin Pihlak)
- Add object access hooks for `DROP` commands (KaiGai Kohei)
- Centralize `DROP` handling for some object types (KaiGai Kohei)
- Add a pg_upgrade test suite (Peter Eisentraut)
- Sync regular expression code with TCL 8.5.11 and improve internal processing (Tom Lane)
- Move CRC tables to libpgport, and provide them in a separate include file (Daniel Farina)
- Add options to git_changelog for use in major release note creation (Bruce Momjian)
- Support Linux's `/proc/self/oom_score_adj` API (Tom Lane)

E.20.3.13. Additional Modules

- Improve efficiency of dblink by using libpq's new single-row processing mode (Kyotaro Horiguchi, Marko Kreen)

  This improvement does not apply to `dblink_send_query()`/`dblink_get_result()`.
- Support `force_not_null` option in file_fdw (Shigeru Hanada)
- Implement dry-run mode for pg_archivecleanup (Gabriele Bartolini)

  This only outputs the names of files to be deleted.
- Add new pgbench switches `--unlogged-tables`, `--tablespace`, and `--index-tablespace` (Robert Haas)
- Change pg_test_fsync to test for a fixed amount of time, rather than a fixed number of cycles (Bruce Momjian)

  The `-o`/cycles option was removed, and `-s`/seconds added.
- Add a pg_test_timing utility to measure clock monotonicity and timing overhead (Ants Aasma, Greg Smith)
- Add a tcn (triggered change notification) module to generate `NOTIFY` events on table changes (Kevin Grittner)

E.20.3.13.1. pg_upgrade

- Adjust pg_upgrade environment variables (Bruce Momjian)

  Rename data, bin, and port environment variables to begin with `PG`, and support `PGPORTOLD`/`PGPORTNEW`, to replace `PGPORT`.
- Overhaul pg_upgrade logging and failure reporting (Bruce Momjian)

Create four append-only log files, and delete them on success. Add `-r`/`--retain` option to unconditionally retain these files. Also remove pg_upgrade options `-g`/`-G`/`-l` options as unnecessary, and tighten log file permissions.

- Make pg_upgrade create a script to incrementally generate more accurate optimizer statistics (Bruce Momjian)

  This reduces the time needed to generate minimal cluster statistics after an upgrade.

- Allow pg_upgrade to upgrade an old cluster that does not have a `postgres` database (Bruce Momjian)
- Allow pg_upgrade to handle cases where some old or new databases are missing, as long as they are empty (Bruce Momjian)
- Allow pg_upgrade to handle configuration-only directory installations (Bruce Momjian)
- In pg_upgrade, add `-o`/`-O` options to pass parameters to the servers (Bruce Momjian)

  This is useful for configuration-only directory installs.

- Change pg_upgrade to use port 50432 by default (Bruce Momjian)

  This helps avoid unintended client connections during the upgrade.

- Reduce cluster locking in pg_upgrade (Bruce Momjian)

  Specifically, only lock the old cluster if link mode is used, and do it right after the schema is restored.

E.20.3.13.2. pg_stat_statements

- Allow pg_stat_statements to aggregate similar queries via SQL text normalization (Peter Geoghegan, Tom Lane)

  Users with applications that use non-parameterized SQL will now be able to monitor query performance without detailed log analysis.

- Add dirtied and written block counts and read/write times to pg_stat_statements (Robert Haas, Ants Aasma)
- Prevent pg_stat_statements from double-counting `PREPARE` and `EXECUTE` commands (Tom Lane)

E.20.3.13.3. sepgsql

- Support `SECURITY LABEL` on global objects (KaiGai Kohei, Robert Haas)

  Specifically, add security labels to databases, tablespaces, and roles.

- Allow sepgsql to honor database labels (KaiGai Kohei)
- Perform sepgsql permission checks during the creation of various objects (KaiGai Kohei)
- Add `sepgsql_setcon()` and related functions to control the sepgsql security domain (KaiGai Kohei)
- Add a user space access cache to sepgsql to improve performance (KaiGai Kohei)

E.20.3.14. Documentation

- Add a rule to optionally build HTML documentation using the stylesheet from the website (Magnus Hagander)

  Use `gmake STYLE=website draft`.
- Improve `EXPLAIN` documentation (Tom Lane)
- Document that user/database names are preserved with double-quoting by command-line tools like vacuumdb (Bruce Momjian)
- Document the actual string returned by the client for MD5 authentication (Cyan Ogilvie)
- Deprecate use of `GLOBAL` and `LOCAL` in `CREATE TEMP TABLE` (Noah Misch)

  PostgreSQL has long treated these keyword as no-ops, and continues to do so; but in future they might mean what the SQL standard says they mean, so applications should avoid using them.

E.21. Release 9.1.15

Release Date: 2015-02-05

This release contains a variety of fixes from 9.1.14. For information about new features in the 9.1 major release, see Section E.36.

E.21.1. Migration to Version 9.1.15

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.14, see Section E.22.

E.21.2. Changes

- Fix buffer overruns in `to_char()` (Bruce Momjian)

  When `to_char()` processes a numeric formatting template calling for a large number of digits, PostgreSQL would read past the end of a buffer. When processing a crafted timestamp formatting template, PostgreSQL would write past the end of a buffer. Either case could crash the server. We have not ruled out the possibility of attacks that lead to privilege escalation, though they seem unlikely. (CVE-2015-0241)
- Fix buffer overrun in replacement `*printf()` functions (Tom Lane)

  PostgreSQL includes a replacement implementation of `printf` and related functions. This code will overrun a stack buffer when formatting a floating point number (conversion specifiers `e`, `E`, `f`, `F`, `g` or `G`) with requested precision greater than about 500. This will crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. A database user can trigger such a buffer overrun through the `to_char()` SQL function. While that is the only affected

core PostgreSQL functionality, extension modules that use printf-family functions may be at risk as well.

This issue primarily affects PostgreSQL on Windows. PostgreSQL uses the system implementation of these functions where adequate, which it is on other modern platforms. (CVE-2015-0242)

- Fix buffer overruns in `contrib/pgcrypto` (Marko Tiikkaja, Noah Misch)

  Errors in memory size tracking within the `pgcrypto` module permitted stack buffer overruns and improper dependence on the contents of uninitialized memory. The buffer overrun cases can crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. (CVE-2015-0243)

- Fix possible loss of frontend/backend protocol synchronization after an error (Heikki Linnakangas)

  If any error occurred while the server was in the middle of reading a protocol message from the client, it could lose synchronization and incorrectly try to interpret part of the message's data as a new protocol message. An attacker able to submit crafted binary data within a command parameter might succeed in injecting his own SQL commands this way. Statement timeout and query cancellation are the most likely sources of errors triggering this scenario. Particularly vulnerable are applications that use a timeout and also submit arbitrary user-crafted data as binary query parameters. Disabling statement timeout will reduce, but not eliminate, the risk of exploit. Our thanks to Emil Lenngren for reporting this issue. (CVE-2015-0244)

- Fix information leak via constraint-violation error messages (Stephen Frost)

  Some server error messages show the values of columns that violate a constraint, such as a unique constraint. If the user does not have `SELECT` privilege on all columns of the table, this could mean exposing values that the user should not be able to see. Adjust the code so that values are displayed only when they came from the SQL command or could be selected by the user. (CVE-2014-8161)

- Lock down regression testing's temporary installations on Windows (Noah Misch)

  Use SSPI authentication to allow connections only from the OS user who launched the test suite. This closes on Windows the same vulnerability previously closed on other platforms, namely that other users might be able to connect to the test postmaster. (CVE-2014-0067)

- Avoid possible data corruption if `ALTER DATABASE SET TABLESPACE` is used to move a database to a new tablespace and then shortly later move it back to its original tablespace (Tom Lane)

- Avoid corrupting tables when `ANALYZE` inside a transaction is rolled back (Andres Freund, Tom Lane, Michael Paquier)

  If the failing transaction had earlier removed the last index, rule, or trigger from the table, the table would be left in a corrupted state with the relevant `pg_class` flags not set though they should be.

- Ensure that unlogged tables are copied correctly during `CREATE DATABASE` or `ALTER DATABASE SET TABLESPACE` (Pavan Deolasee, Andres Freund)

- Fix `DROP`'s dependency searching to correctly handle the case where a table column is recursively visited before its table (Petr Jelinek, Tom Lane)

  This case is only known to arise when an extension creates both a datatype and a table using that datatype. The faulty code might refuse a `DROP EXTENSION` unless `CASCADE` is specified, which should not be required.

- Fix use-of-already-freed-memory problem in EvalPlanQual processing (Tom Lane)

  In `READ COMMITTED` mode, queries that lock or update recently-updated rows could crash as a result of this bug.

- Fix planning of `SELECT FOR UPDATE` when using a partial index on a child table (Kyotaro Horiguchi)

In `READ COMMITTED` mode, `SELECT FOR UPDATE` must also recheck the partial index's `WHERE` condition when rechecking a recently-updated row to see if it still satisfies the query's `WHERE` condition. This requirement was missed if the index belonged to an inheritance child table, so that it was possible to incorrectly return rows that no longer satisfy the query condition.

- Fix corner case wherein `SELECT FOR UPDATE` could return a row twice, and possibly miss returning other rows (Tom Lane)

  In `READ COMMITTED` mode, a `SELECT FOR UPDATE` that is scanning an inheritance tree could incorrectly return a row from a prior child table instead of the one it should return from a later child table.

- Reject duplicate column names in the referenced-columns list of a `FOREIGN KEY` declaration (David Rowley)

  This restriction is per SQL standard. Previously we did not reject the case explicitly, but later on the code would fail with bizarre-looking errors.

- Fix bugs in raising a `numeric` value to a large integral power (Tom Lane)

  The previous code could get a wrong answer, or consume excessive amounts of time and memory before realizing that the answer must overflow.

- In `numeric_recv()`, truncate away any fractional digits that would be hidden according to the value's `dscale` field (Tom Lane)

  A `numeric` value's display scale (`dscale`) should never be less than the number of nonzero fractional digits; but apparently there's at least one broken client application that transmits binary `numeric` values in which that's true. This leads to strange behavior since the extra digits are taken into account by arithmetic operations even though they aren't printed. The least risky fix seems to be to truncate away such "hidden" digits on receipt, so that the value is indeed what it prints as.

- Reject out-of-range numeric timezone specifications (Tom Lane)

  Simple numeric timezone specifications exceeding +/- 168 hours (one week) would be accepted, but could then cause null-pointer dereference crashes in certain operations. There's no use-case for such large UTC offsets, so reject them.

- Fix bugs in `tsquery @> tsquery` operator (Heikki Linnakangas)

  Two different terms would be considered to match if they had the same CRC. Also, if the second operand had more terms than the first, it would be assumed not to be contained in the first; which is wrong since it might contain duplicate terms.

- Improve ispell dictionary's defenses against bad affix files (Tom Lane)

- Allow more than 64K phrases in a thesaurus dictionary (David Boutin)

  The previous coding could crash on an oversize dictionary, so this was deemed a back-patchable bug fix rather than a feature addition.

- Fix namespace handling in `xpath()` (Ali Akbar)

  Previously, the `xml` value resulting from an `xpath()` call would not have namespace declarations if the namespace declarations were attached to an ancestor element in the input `xml` value, rather than to the specific element being returned. Propagate the ancestral declaration so that the result is correct when considered in isolation.

- Fix planner problems with nested append relations, such as inherited tables within `UNION ALL` subqueries (Tom Lane)

- Fail cleanly when a GiST index tuple doesn't fit on a page, rather than going into infinite recursion (Andrew Gierth)

- Exempt tables that have per-table `cost_limit` and/or `cost_delay` settings from autovacuum's global cost balancing rules (Álvaro Herrera)

  The previous behavior resulted in basically ignoring these per-table settings, which was unintended. Now, a table having such settings will be vacuumed using those settings, independently of what is going on in other autovacuum workers. This may result in heavier total I/O load than before, so such settings should be re-examined for sanity.

- Avoid wholesale autovacuuming when autovacuum is nominally off (Tom Lane)

  Even when autovacuum is nominally off, we will still launch autovacuum worker processes to vacuum tables that are at risk of XID wraparound. However, such a worker process then proceeded to vacuum all tables in the target database, if they met the usual thresholds for autovacuuming. This is at best pretty unexpected; at worst it delays response to the wraparound threat. Fix it so that if autovacuum is turned off, workers *only* do anti-wraparound vacuums and not any other work.

- During crash recovery, ensure that unlogged relations are rewritten as empty and are synced to disk before recovery is considered complete (Abhijit Menon-Sen, Andres Freund)

  This prevents scenarios in which unlogged relations might contain garbage data following database crash recovery.

- Fix race condition between hot standby queries and replaying a full-page image (Heikki Linnakangas)

  This mistake could result in transient errors in queries being executed in hot standby.

- Fix several cases where recovery logic improperly ignored WAL records for `COMMIT/ABORT PREPARED` (Heikki Linnakangas)

  The most notable oversight was that `recovery_min_apply_delay` failed to delay application of a two-phase commit.

- Avoid creating unnecessary `.ready` marker files for timeline history files (Fujii Masao)

- Fix possible null pointer dereference when an empty prepared statement is used and the `log_statement` setting is `mod` or `ddl` (Fujii Masao)

- Change "pgstat wait timeout" warning message to be LOG level, and rephrase it to be more understandable (Tom Lane)

  This message was originally thought to be essentially a can't-happen case, but it occurs often enough on our slower buildfarm members to be a nuisance. Reduce it to LOG level, and expend a bit more effort on the wording: it now reads "using stale statistics instead of current ones because stats collector is not responding".

- Fix SPARC spinlock implementation to ensure correctness if the CPU is being run in a non-TSO coherency mode, as some non-Solaris kernels do (Andres Freund)

- Warn if OS X's `setlocale()` starts an unwanted extra thread inside the postmaster (Noah Misch)

- Fix processing of repeated `dbname` parameters in `PQconnectdbParams()` (Alex Shulgin)

  Unexpected behavior ensued if the first occurrence of `dbname` contained a connection string or URI to be expanded.

- Ensure that libpq reports a suitable error message on unexpected socket EOF (Marko Tiikkaja, Tom Lane)

  Depending on kernel behavior, libpq might return an empty error string rather than something useful when the server unexpectedly closed the socket.

- Clear any old error message during `PQreset()` (Heikki Linnakangas)

If `PQreset()` is called repeatedly, and the connection cannot be re-established, error messages from the failed connection attempts kept accumulating in the `PGconn`'s error string.

- Properly handle out-of-memory conditions while parsing connection options in libpq (Alex Shulgin, Heikki Linnakangas)
- Fix array overrun in ecpg's version of `ParseDateTime()` (Michael Paquier)
- In initdb, give a clearer error message if a password file is specified but is empty (Mats Erik Andersson)
- Fix psql's `\s` command to work nicely with libedit, and add pager support (Stepan Rutz, Tom Lane)

  When using libedit rather than readline, `\s` printed the command history in a fairly unreadable encoded format, and on recent libedit versions might fail altogether. Fix that by printing the history ourselves rather than having the library do it. A pleasant side-effect is that the pager is used if appropriate.

  This patch also fixes a bug that caused newline encoding to be applied inconsistently when saving the command history with libedit. Multiline history entries written by older psql versions will be read cleanly with this patch, but perhaps not vice versa, depending on the exact libedit versions involved.
- Improve consistency of parsing of psql's special variables (Tom Lane)

  Allow variant spellings of `on` and `off` (such as `1`/`0`) for `ECHO_HIDDEN` and `ON_ERROR_ROLLBACK`. Report a warning for unrecognized values for `COMP_KEYWORD_CASE`, `ECHO`, `ECHO_HIDDEN`, `HISTCONTROL`, `ON_ERROR_ROLLBACK`, and `VERBOSITY`. Recognize all values for all these variables case-insensitively; previously there was a mishmash of case-sensitive and case-insensitive behaviors.
- Fix psql's expanded-mode display to work consistently when using `border` = 3 and `linestyle` = `ascii` or `unicode` (Stephen Frost)
- Improve performance of pg_dump when the database contains many instances of multiple dependency paths between the same two objects (Tom Lane)
- Fix possible deadlock during parallel restore of a schema-only dump (Robert Haas, Tom Lane)
- Fix core dump in `pg_dump --binary-upgrade` on zero-column composite type (Rushabh Lathia)
- Prevent WAL files created by `pg_basebackup -x/-X` from being archived again when the standby is promoted (Andres Freund)
- Fix upgrade-from-unpackaged script for `contrib/citext` (Tom Lane)
- Fix block number checking in `contrib/pageinspect`'s `get_raw_page()` (Tom Lane)

  The incorrect checking logic could prevent access to some pages in non-main relation forks.
- Fix `contrib/pgcrypto`'s `pgp_sym_decrypt()` to not fail on messages whose length is 6 less than a power of 2 (Marko Tiikkaja)
- Fix file descriptor leak in `contrib/pg_test_fsync` (Jeff Janes)

  This could cause failure to remove temporary files on Windows.
- Handle unexpected query results, especially NULLs, safely in `contrib/tablefunc`'s `connectby()` (Michael Paquier)

  `connectby()` previously crashed if it encountered a NULL key value. It now prints that row but doesn't recurse further.
- Avoid a possible crash in `contrib/xml2`'s `xslt_process()` (Mark Simonetti)

libxslt seems to have an undocumented dependency on the order in which resources are freed; reorder our calls to avoid a crash.

- Mark some `contrib` I/O functions with correct volatility properties (Tom Lane)

  The previous over-conservative marking was immaterial in normal use, but could cause optimization problems or rejection of valid index expression definitions. Since the consequences are not large, we've just adjusted the function definitions in the extension modules' scripts, without changing version numbers.

- Numerous cleanups of warnings from Coverity static code analyzer (Andres Freund, Tatsuo Ishii, Marko Kreen, Tom Lane, Michael Paquier)

  These changes are mostly cosmetic but in some cases fix corner-case bugs, for example a crash rather than a proper error report after an out-of-memory failure. None are believed to represent security issues.

- Detect incompatible OpenLDAP versions during build (Noah Misch)

  With OpenLDAP versions 2.4.24 through 2.4.31, inclusive, PostgreSQL backends can crash at exit. Raise a warning during configure based on the compile-time OpenLDAP version number, and test the crashing scenario in the `contrib/dblink` regression test.

- In non-MSVC Windows builds, ensure `libpq.dll` is installed with execute permissions (Noah Misch)

- Make pg_regress remove any temporary installation it created upon successful exit (Tom Lane)

  This results in a very substantial reduction in disk space usage during `make check-world`, since that sequence involves creation of numerous temporary installations.

- Support time zone abbreviations that change UTC offset from time to time (Tom Lane)

  Previously, PostgreSQL assumed that the UTC offset associated with a time zone abbreviation (such as `EST`) never changes in the usage of any particular locale. However this assumption fails in the real world, so introduce the ability for a zone abbreviation to represent a UTC offset that sometimes changes. Update the zone abbreviation definition files to make use of this feature in timezone locales that have changed the UTC offset of their abbreviations since 1970 (according to the IANA timezone database). In such timezones, PostgreSQL will now associate the correct UTC offset with the abbreviation depending on the given date.

- Update time zone abbreviations lists (Tom Lane)

  Add CST (China Standard Time) to our lists. Remove references to ADT as "Arabia Daylight Time", an abbreviation that's been out of use since 2007; therefore, claiming there is a conflict with "Atlantic Daylight Time" doesn't seem especially helpful. Fix entirely incorrect GMT offsets for CKT (Cook Islands), FJT, and FJST (Fiji); we didn't even have them on the proper side of the date line.

- Update time zone data files to tzdata release 2015a.

  The IANA timezone database has adopted abbreviations of the form `AxST`/`AxDT` for all Australian time zones, reflecting what they believe to be current majority practice Down Under. These names do not conflict with usage elsewhere (other than ACST for Acre Summer Time, which has been in disuse since 1994). Accordingly, adopt these names into our "Default" timezone abbreviation set. The "Australia" abbreviation set now contains only CST, EAST, EST, SAST, SAT, and WST, all of which are thought to be mostly historical usage. Note that SAST has also been changed to be South Africa Standard Time in the "Default" abbreviation set.

  Also, add zone abbreviations SRET (Asia/Srednekolymsk) and XJT (Asia/Urumqi), and use WSST/WSDT for western Samoa. Also, there were DST law changes in Chile, Mexico, the Turks

& Caicos Islands (America/Grand_Turk), and Fiji. There is a new zone Pacific/Bougainville for portions of Papua New Guinea. Also, numerous corrections for historical (pre-1970) time zone data.

E.22. Release 9.1.14

Release Date: 2014-07-24

This release contains a variety of fixes from 9.1.13. For information about new features in the 9.1 major release, see Section E.36.

E.22.1. Migration to Version 9.1.14

A dump/restore is not required for those running 9.1.X.

However, this release corrects an index corruption problem in some GiST indexes. See the first changelog entry below to find out whether your installation has been affected and what steps you should take if so.

Also, if you are upgrading from a version earlier than 9.1.11, see Section E.25.

E.22.2. Changes

- Correctly initialize padding bytes in `contrib/btree_gist` indexes on `bit` columns (Heikki Linnakangas)

  This error could result in incorrect query results due to values that should compare equal not being seen as equal. Users with GiST indexes on `bit` or `bit varying` columns should `REINDEX` those indexes after installing this update.

- Protect against torn pages when deleting GIN list pages (Heikki Linnakangas)

  This fix prevents possible index corruption if a system crash occurs while the page update is being written to disk.

- Don't clear the right-link of a GiST index page while replaying updates from WAL (Heikki Linnakangas)

  This error could lead to transiently wrong answers from GiST index scans performed in Hot Standby.

- Fix feedback status when hot_standby_feedback is turned off on-the-fly (Simon Riggs)

- Fix possibly-incorrect cache invalidation during nested calls to `ReceiveSharedInvalidMessages` (Andres Freund)

- Fix "could not find pathkey item to sort" planner failures with `UNION ALL` over subqueries reading from tables with inheritance children (Tom Lane)

- Don't assume a subquery's output is unique if there's a set-returning function in its targetlist (David Rowley)

This oversight could lead to misoptimization of constructs like `WHERE x IN (SELECT y, generate_series(1,10) FROM t GROUP BY y)`.

- Fix failure to detoast fields in composite elements of structured types (Tom Lane)

  This corrects cases where TOAST pointers could be copied into other tables without being dereferenced. If the original data is later deleted, it would lead to errors like "missing chunk number 0 for toast value ..." when the now-dangling pointer is used.

- Fix "record type has not been registered" failures with whole-row references to the output of Append plan nodes (Tom Lane)
- Fix possible crash when invoking a user-defined function while rewinding a cursor (Tom Lane)
- Fix query-lifespan memory leak while evaluating the arguments for a function in `FROM` (Tom Lane)
- Fix session-lifespan memory leaks in regular-expression processing (Tom Lane, Arthur O'Dwyer, Greg Stark)
- Fix data encoding error in `hungarian.stop` (Tom Lane)
- Prevent foreign tables from being created with OIDS when default_with_oids is true (Etsuro Fujita)
- Fix liveness checks for rows that were inserted in the current transaction and then deleted by a now-rolled-back subtransaction (Andres Freund)

  This could cause problems (at least spurious warnings, and at worst an infinite loop) if `CREATE INDEX` or `CLUSTER` were done later in the same transaction.

- Clear `pg_stat_activity.xact_start` during `PREPARE TRANSACTION` (Andres Freund)

  After the `PREPARE`, the originating session is no longer in a transaction, so it should not continue to display a transaction start time.

- Fix `REASSIGN OWNED` to not fail for text search objects (Álvaro Herrera)
- Block signals during postmaster startup (Tom Lane)

  This ensures that the postmaster will properly clean up after itself if, for example, it receives SIGINT while still starting up.

- Fix client host name lookup when processing `pg_hba.conf` entries that specify host names instead of IP addresses (Tom Lane)

  Ensure that reverse-DNS lookup failures are reported, instead of just silently not matching such entries. Also ensure that we make only one reverse-DNS lookup attempt per connection, not one per host name entry, which is what previously happened if the lookup attempts failed.

- Secure Unix-domain sockets of temporary postmasters started during `make check` (Noah Misch)

  Any local user able to access the socket file could connect as the server's bootstrap superuser, then proceed to execute arbitrary code as the operating-system user running the test, as we previously noted in CVE-2014-0067. This change defends against that risk by placing the server's socket in a temporary, mode 0700 subdirectory of `/tmp`. The hazard remains however on platforms where Unix sockets are not supported, notably Windows, because then the temporary postmaster must accept local TCP connections.

  A useful side effect of this change is to simplify `make check` testing in builds that override `DEFAULT_PGSOCKET_DIR`. Popular non-default values like `/var/run/postgresql` are often not writable by the build user, requiring workarounds that will no longer be necessary.

- Fix tablespace creation WAL replay to work on Windows (MauMau)
- Fix detection of socket creation failures on Windows (Bruce Momjian)

- On Windows, allow new sessions to absorb values of PGC_BACKEND parameters (such as log_connections) from the configuration file (Amit Kapila)

  Previously, if such a parameter were changed in the file post-startup, the change would have no effect.

- Properly quote executable path names on Windows (Nikhil Deshpande)

  This oversight could cause initdb and pg_upgrade to fail on Windows, if the installation path contained both spaces and `@` signs.

- Fix linking of libpython on OS X (Tom Lane)

  The method we previously used can fail with the Python library supplied by Xcode 5.0 and later.

- Avoid buffer bloat in libpq when the server consistently sends data faster than the client can absorb it (Shin-ichi Morita, Tom Lane)

  libpq could be coerced into enlarging its input buffer until it runs out of memory (which would be reported misleadingly as "lost synchronization with server"). Under ordinary circumstances it's quite far-fetched that data could be continuously transmitted more quickly than the `recv()` loop can absorb it, but this has been observed when the client is artificially slowed by scheduler constraints.

- Ensure that LDAP lookup attempts in libpq time out as intended (Laurenz Albe)

- Fix ecpg to do the right thing when an array of `char *` is the target for a FETCH statement returning more than one row, as well as some other array-handling fixes (Ashutosh Bapat)

- Fix pg_restore's processing of old-style large object comments (Tom Lane)

  A direct-to-database restore from an archive file generated by a pre-9.0 version of pg_dump would usually fail if the archive contained more than a few comments for large objects.

- In `contrib/pgcrypto` functions, ensure sensitive information is cleared from stack variables before returning (Marko Kreen)

- In `contrib/uuid-ossp`, cache the state of the OSSP UUID library across calls (Tom Lane)

  This improves the efficiency of UUID generation and reduces the amount of entropy drawn from `/dev/urandom`, on platforms that have that.

- Update time zone data files to tzdata release 2014e for DST law changes in Crimea, Egypt, and Morocco.

E.23. Release 9.1.13

Release Date: 2014-03-20

This release contains a variety of fixes from 9.1.12. For information about new features in the 9.1 major release, see Section E.36.

E.23.1. Migration to Version 9.1.13

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.11, see Section E.25.

E.23.2. Changes

- Restore GIN metapages unconditionally to avoid torn-page risk (Heikki Linnakangas)

  Although this oversight could theoretically result in a corrupted index, it is unlikely to have caused any problems in practice, since the active part of a GIN metapage is smaller than a standard 512-byte disk sector.

- Avoid race condition in checking transaction commit status during receipt of a `NOTIFY` message (Marko Tiikkaja)

  This prevents a scenario wherein a sufficiently fast client might respond to a notification before database updates made by the notifier have become visible to the recipient.

- Allow regular-expression operators to be terminated early by query cancel requests (Tom Lane)

  This prevents scenarios wherein a pathological regular expression could lock up a server process uninterruptably for a long time.

- Remove incorrect code that tried to allow `OVERLAPS` with single-element row arguments (Joshua Yanovski)

  This code never worked correctly, and since the case is neither specified by the SQL standard nor documented, it seemed better to remove it than fix it.

- Avoid getting more than `AccessShareLock` when de-parsing a rule or view (Dean Rasheed)

  This oversight resulted in pg_dump unexpectedly acquiring `RowExclusiveLock` locks on tables mentioned as the targets of `INSERT`/`UPDATE`/`DELETE` commands in rules. While usually harmless, that could interfere with concurrent transactions that tried to acquire, for example, `ShareLock` on those tables.

- Improve performance of index endpoint probes during planning (Tom Lane)

  This change fixes a significant performance problem that occurred when there were many not-yet-committed rows at the end of the index, which is a common situation for indexes on sequentially-assigned values such as timestamps or sequence-generated identifiers.

- Fix walsender's failure to shut down cleanly when client is pg_receivexlog (Fujii Masao)

- Fix test to see if hot standby connections can be allowed immediately after a crash (Heikki Linnakangas)

- Prevent interrupts while reporting non-`ERROR` messages (Tom Lane)

  This guards against rare server-process freezeups due to recursive entry to `syslog()`, and perhaps other related problems.

- Fix memory leak in PL/Perl when returning a composite result, including multiple-OUT-parameter cases (Alex Hunsaker)

- Prevent intermittent "could not reserve shared memory region" failures on recent Windows versions (MauMau)

- Update time zone data files to tzdata release 2014a for DST law changes in Fiji and Turkey, plus historical changes in Israel and Ukraine.

E.24. Release 9.1.12

Release Date: 2014-02-20

This release contains a variety of fixes from 9.1.11. For information about new features in the 9.1 major release, see Section E.36.

E.24.1. Migration to Version 9.1.12

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.11, see Section E.25.

E.24.2. Changes

- Shore up `GRANT ... WITH ADMIN OPTION` restrictions (Noah Misch)

  Granting a role without `ADMIN OPTION` is supposed to prevent the grantee from adding or removing members from the granted role, but this restriction was easily bypassed by doing `SET ROLE` first. The security impact is mostly that a role member can revoke the access of others, contrary to the wishes of his grantor. Unapproved role member additions are a lesser concern, since an uncooperative role member could provide most of his rights to others anyway by creating views or `SECURITY DEFINER` functions. (CVE-2014-0060)

- Prevent privilege escalation via manual calls to PL validator functions (Andres Freund)

  The primary role of PL validator functions is to be called implicitly during `CREATE FUNCTION`, but they are also normal SQL functions that a user can call explicitly. Calling a validator on a function actually written in some other language was not checked for and could be exploited for privilege-escalation purposes. The fix involves adding a call to a privilege-checking function in each validator function. Non-core procedural languages will also need to make this change to their own validator functions, if any. (CVE-2014-0061)

- Avoid multiple name lookups during table and index DDL (Robert Haas, Andres Freund)

  If the name lookups come to different conclusions due to concurrent activity, we might perform some parts of the DDL on a different table than other parts. At least in the case of `CREATE INDEX`, this can be used to cause the permissions checks to be performed against a different table than the index creation, allowing for a privilege escalation attack. (CVE-2014-0062)

- Prevent buffer overrun with long datetime strings (Noah Misch)

  The `MAXDATELEN` constant was too small for the longest possible value of type `interval`, allowing a buffer overrun in `interval_out()`. Although the datetime input functions were more careful about avoiding buffer overrun, the limit was short enough to cause them to reject some valid inputs, such as input containing a very long timezone name. The ecpg library contained these vulnerabilities along with some of its own. (CVE-2014-0063)

- Prevent buffer overrun due to integer overflow in size calculations (Noah Misch, Heikki Linnakangas)

Several functions, mostly type input functions, calculated an allocation size without checking for overflow. If overflow did occur, a too-small buffer would be allocated and then written past. (CVE-2014-0064)

- Prevent overruns of fixed-size buffers (Peter Eisentraut, Jozef Mlich)

  Use `strlcpy()` and related functions to provide a clear guarantee that fixed-size buffers are not overrun. Unlike the preceding items, it is unclear whether these cases really represent live issues, since in most cases there appear to be previous constraints on the size of the input string. Nonetheless it seems prudent to silence all Coverity warnings of this type. (CVE-2014-0065)

- Avoid crashing if `crypt()` returns NULL (Honza Horak, Bruce Momjian)

  There are relatively few scenarios in which `crypt()` could return NULL, but `contrib/chkpass` would crash if it did. One practical case in which this could be an issue is if libc is configured to refuse to execute unapproved hashing algorithms (e.g., "FIPS mode"). (CVE-2014-0066)

- Document risks of `make check` in the regression testing instructions (Noah Misch, Tom Lane)

  Since the temporary server started by `make check` uses "trust" authentication, another user on the same machine could connect to it as database superuser, and then potentially exploit the privileges of the operating-system user who started the tests. A future release will probably incorporate changes in the testing procedure to prevent this risk, but some public discussion is needed first. So for the moment, just warn people against using `make check` when there are untrusted users on the same machine. (CVE-2014-0067)

- Fix possible mis-replay of WAL records when some segments of a relation aren't full size (Greg Stark, Tom Lane)

  The WAL update could be applied to the wrong page, potentially many pages past where it should have been. Aside from corrupting data, this error has been observed to result in significant "bloat" of standby servers compared to their masters, due to updates being applied far beyond where the end-of-file should have been. This failure mode does not appear to be a significant risk during crash recovery, only when initially synchronizing a standby created from a base backup taken from a quickly-changing master.

- Fix bug in determining when recovery has reached consistency (Tomonari Katsumata, Heikki Linnakangas)

  In some cases WAL replay would mistakenly conclude that the database was already consistent at the start of replay, thus possibly allowing hot-standby queries before the database was really consistent. Other symptoms such as "PANIC: WAL contains references to invalid pages" were also possible.

- Fix improper locking of btree index pages while replaying a `VACUUM` operation in hot-standby mode (Andres Freund, Heikki Linnakangas, Tom Lane)

  This error could result in "PANIC: WAL contains references to invalid pages" failures.

- Ensure that insertions into non-leaf GIN index pages write a full-page WAL record when appropriate (Heikki Linnakangas)

  The previous coding risked index corruption in the event of a partial-page write during a system crash.

- When `pause_at_recovery_target` and `recovery_target_inclusive` are both set, ensure the target record is applied before pausing, not after (Heikki Linnakangas)

- Fix race conditions during server process exit (Robert Haas)

  Ensure that signal handlers don't attempt to use the process's `MyProc` pointer after it's no longer valid.

- Fix race conditions in walsender shutdown logic and walreceiver SIGHUP signal handler (Tom Lane)
- Fix unsafe references to `errno` within error reporting logic (Christian Kruse)

  This would typically lead to odd behaviors such as missing or inappropriate `HINT` fields.
- Fix possible crashes from using `ereport()` too early during server startup (Tom Lane)

  The principal case we've seen in the field is a crash if the server is started in a directory it doesn't have permission to read.
- Clear retry flags properly in OpenSSL socket write function (Alexander Kukushkin)

  This omission could result in a server lockup after unexpected loss of an SSL-encrypted connection.
- Fix length checking for Unicode identifiers (`U&"..."` syntax) containing escapes (Tom Lane)

  A spurious truncation warning would be printed for such identifiers if the escaped form of the identifier was too long, but the identifier actually didn't need truncation after de-escaping.
- Allow keywords that are type names to be used in lists of roles (Stephen Frost)

  A previous patch allowed such keywords to be used without quoting in places such as role identifiers; but it missed cases where a list of role identifiers was permitted, such as `DROP ROLE`.
- Fix parser crash for `EXISTS(SELECT * FROM zero_column_table)` (Tom Lane)
- Fix possible crash due to invalid plan for nested sub-selects, such as `WHERE (... x IN (SELECT ...) ...) IN (SELECT ...)` (Tom Lane)
- Ensure that `ANALYZE` creates statistics for a table column even when all the values in it are "too wide" (Tom Lane)

  `ANALYZE` intentionally omits very wide values from its histogram and most-common-values calculations, but it neglected to do something sane in the case that all the sampled entries are too wide.
- In `ALTER TABLE ... SET TABLESPACE`, allow the database's default tablespace to be used without a permissions check (Stephen Frost)

  `CREATE TABLE` has always allowed such usage, but `ALTER TABLE` didn't get the memo.
- Fix "cannot accept a set" error when some arms of a `CASE` return a set and others don't (Tom Lane)
- Fix checks for all-zero client addresses in pgstat functions (Kevin Grittner)
- Fix possible misclassification of multibyte characters by the text search parser (Tom Lane)

  Non-ASCII characters could be misclassified when using C locale with a multibyte encoding. On Cygwin, non-C locales could fail as well.
- Fix possible misbehavior in `plainto_tsquery()` (Heikki Linnakangas)

  Use `memmove()` not `memcpy()` for copying overlapping memory regions. There have been no field reports of this actually causing trouble, but it's certainly risky.
- Fix placement of permissions checks in `pg_start_backup()` and `pg_stop_backup()` (Andres Freund, Magnus Hagander)

  The previous coding might attempt to do catalog access when it shouldn't.
- Accept `SHIFT_JIS` as an encoding name for locale checking purposes (Tatsuo Ishii)
- Fix misbehavior of `PQhost()` on Windows (Fujii Masao)

  It should return `localhost` if no host has been specified.

- Improve error handling in libpq and psql for failures during `COPY TO STDOUT/FROM STDIN` (Tom Lane)

  In particular this fixes an infinite loop that could occur in 9.2 and up if the server connection was lost during `COPY FROM STDIN`. Variants of that scenario might be possible in older versions, or with other client applications.

- Fix possible incorrect printing of filenames in pg_basebackup's verbose mode (Magnus Hagander)
- Avoid including tablespaces inside PGDATA twice in base backups (Dimitri Fontaine, Magnus Hagander)
- Fix misaligned descriptors in ecpg (MauMau)
- In ecpg, handle lack of a hostname in the connection parameters properly (Michael Meskes)
- Fix performance regression in `contrib/dblink` connection startup (Joe Conway)

  Avoid an unnecessary round trip when client and server encodings match.

- In `contrib/isn`, fix incorrect calculation of the check digit for ISMN values (Fabien Coelho)
- Ensure client-code-only installation procedure works as documented (Peter Eisentraut)
- In Mingw and Cygwin builds, install the libpq DLL in the `bin` directory (Andrew Dunstan)

  This duplicates what the MSVC build has long done. It should fix problems with programs like psql failing to start because they can't find the DLL.

- Avoid using the deprecated `dllwrap` tool in Cygwin builds (Marco Atzeri)
- Don't generate plain-text `HISTORY` and `src/test/regress/README` files anymore (Tom Lane)

  These text files duplicated the main HTML and PDF documentation formats. The trouble involved in maintaining them greatly outweighs the likely audience for plain-text format. Distribution tarballs will still contain files by these names, but they'll just be stubs directing the reader to consult the main documentation. The plain-text `INSTALL` file will still be maintained, as there is arguably a use-case for that.

- Update time zone data files to tzdata release 2013i for DST law changes in Jordan and historical changes in Cuba.

  In addition, the zones `Asia/Riyadh87`, `Asia/Riyadh88`, and `Asia/Riyadh89` have been removed, as they are no longer maintained by IANA, and never represented actual civil timekeeping practice.

E.25. Release 9.1.11

Release Date: 2013-12-05

This release contains a variety of fixes from 9.1.10. For information about new features in the 9.1 major release, see Section E.36.

E.25.1. Migration to Version 9.1.11

A dump/restore is not required for those running 9.1.X.

However, this release corrects a number of potential data corruption issues. See the first two changelog entries below to find out whether your installation has been affected and what steps you can take if so.

Also, if you are upgrading from a version earlier than 9.1.9, see Section E.27.

E.25.2. Changes

- Fix `VACUUM`'s tests to see whether it can update `relfrozenxid` (Andres Freund)

  In some cases `VACUUM` (either manual or autovacuum) could incorrectly advance a table's `relfrozenxid` value, allowing tuples to escape freezing, causing those rows to become invisible once 2^31 transactions have elapsed. The probability of data loss is fairly low since multiple incorrect advancements would need to happen before actual loss occurs, but it's not zero. Users upgrading from releases 9.0.4 or 8.4.8 or earlier are not affected, but all later versions contain the bug.

  The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix any latent corruption but will not be able to fix all pre-existing data errors. However, an installation can be presumed safe after performing this vacuuming if it has executed fewer than 2^31 update transactions in its lifetime (check this with `SELECT txid_current() < 2^31`).

- Fix initialization of `pg_clog` and `pg_subtrans` during hot standby startup (Andres Freund, Heikki Linnakangas)

  This bug can cause data loss on standby servers at the moment they start to accept hot-standby queries, by marking committed transactions as uncommitted. The likelihood of such corruption is small unless, at the time of standby startup, the primary server has executed many updating transactions since its last checkpoint. Symptoms include missing rows, rows that should have been deleted being still visible, and obsolete versions of updated rows being still visible alongside their newer versions.

  This bug was introduced in versions 9.3.0, 9.2.5, 9.1.10, and 9.0.14. Standby servers that have only been running earlier releases are not at risk. It's recommended that standby servers that have ever run any of the buggy releases be re-cloned from the primary (e.g., with a new base backup) after upgrading.

- Truncate `pg_multixact` contents during WAL replay (Andres Freund)

  This avoids ever-increasing disk space consumption in standby servers.

- Fix race condition in GIN index posting tree page deletion (Heikki Linnakangas)

  This could lead to transient wrong answers or query failures.

- Avoid flattening a subquery whose `SELECT` list contains a volatile function wrapped inside a sub-`SELECT` (Tom Lane)

  This avoids unexpected results due to extra evaluations of the volatile function.

- Fix planner's processing of non-simple-variable subquery outputs nested within outer joins (Tom Lane)

  This error could lead to incorrect plans for queries involving multiple levels of subqueries within `JOIN` syntax.

- Fix incorrect generation of optimized MIN()/MAX() plans for inheritance trees (Tom Lane)

The planner could fail in cases where the MIN()/MAX() argument was an expression rather than a simple variable.

- Fix premature deletion of temporary files (Andres Freund)
- Fix possible read past end of memory in rule printing (Peter Eisentraut)
- Fix array slicing of `int2vector` and `oidvector` values (Tom Lane)

  Expressions of this kind are now implicitly promoted to regular `int2` or `oid` arrays.
- Fix incorrect behaviors when using a SQL-standard, simple GMT offset timezone (Tom Lane)

  In some cases, the system would use the simple GMT offset value when it should have used the regular timezone setting that had prevailed before the simple offset was selected. This change also causes the `timeofday` function to honor the simple GMT offset zone.
- Prevent possible misbehavior when logging translations of Windows error codes (Tom Lane)
- Properly quote generated command lines in pg_ctl (Naoya Anzai and Tom Lane)

  This fix applies only to Windows.
- Fix pg_dumpall to work when a source database sets `default_transaction_read_only` via `ALTER DATABASE SET` (Kevin Grittner)

  Previously, the generated script would fail during restore.
- Make ecpg search for quoted cursor names case-sensitively (Zoltán Böszörményi)
- Fix ecpg's processing of lists of variables declared `varchar` (Zoltán Böszörményi)
- Make `contrib/lo` defend against incorrect trigger definitions (Marc Cousin)
- Update time zone data files to tzdata release 2013h for DST law changes in Argentina, Brazil, Jordan, Libya, Liechtenstein, Morocco, and Palestine. Also, new timezone abbreviations WIB, WIT, WITA for Indonesia.

E.26. Release 9.1.10

Release Date: 2013-10-10

This release contains a variety of fixes from 9.1.9. For information about new features in the 9.1 major release, see Section E.36.

E.26.1. Migration to Version 9.1.10

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.9, see Section E.27.

E.26.2. Changes

- Prevent corruption of multi-byte characters when attempting to case-fold identifiers (Andrew Dunstan)

PostgreSQL case-folds non-ASCII characters only when using a single-byte server encoding.

- Fix checkpoint memory leak in background writer when `wal_level = hot_standby` (Naoya Anzai)
- Fix memory leak caused by `lo_open()` failure (Heikki Linnakangas)
- Fix memory overcommit bug when `work_mem` is using more than 24GB of memory (Stephen Frost)
- Serializable snapshot fixes (Kevin Grittner, Heikki Linnakangas)
- Fix deadlock bug in libpq when using SSL (Stephen Frost)
- Fix possible SSL state corruption in threaded libpq applications (Nick Phillips, Stephen Frost)
- Properly compute row estimates for boolean columns containing many NULL values (Andrew Gierth)

  Previously tests like `col IS NOT TRUE` and `col IS NOT FALSE` did not properly factor in NULL values when estimating plan costs.
- Prevent pushing down `WHERE` clauses into unsafe `UNION/INTERSECT` subqueries (Tom Lane)

  Subqueries of a `UNION` or `INTERSECT` that contain set-returning functions or volatile functions in their `SELECT` lists could be improperly optimized, leading to run-time errors or incorrect query results.
- Fix rare case of "failed to locate grouping columns" planner failure (Tom Lane)
- Fix pg_dump of foreign tables with dropped columns (Andrew Dunstan)

  Previously such cases could cause a pg_upgrade error.
- Reorder pg_dump processing of extension-related rules and event triggers (Joe Conway)
- Force dumping of extension tables if specified by `pg_dump -t` or `-n` (Joe Conway)
- Improve view dumping code's handling of dropped columns in referenced tables (Tom Lane)
- Fix `pg_restore -l` with the directory archive to display the correct format name (Fujii Masao)
- Properly record index comments created using `UNIQUE` and `PRIMARY KEY` syntax (Andres Freund)

  This fixes a parallel pg_restore failure.
- Properly guarantee transmission of WAL files before clean switchover (Fujii Masao)

  Previously, the streaming replication connection might close before all WAL files had been replayed on the standby.
- Fix WAL segment timeline handling during recovery (Mitsumasa Kondo, Heikki Linnakangas)

  WAL file recycling during standby recovery could lead to premature recovery completion, resulting in data loss.
- Fix `REINDEX TABLE` and `REINDEX DATABASE` to properly revalidate constraints and mark invalidated indexes as valid (Noah Misch)

  `REINDEX INDEX` has always worked properly.
- Fix possible deadlock during concurrent `CREATE INDEX CONCURRENTLY` operations (Tom Lane)
- Fix `regexp_matches()` handling of zero-length matches (Jeevan Chalke)

  Previously, zero-length matches like '^' could return too many matches.
- Fix crash for overly-complex regular expressions (Heikki Linnakangas)
- Fix regular expression match failures for back references combined with non-greedy quantifiers (Jeevan Chalke)

- Prevent `CREATE FUNCTION` from checking `SET` variables unless function body checking is enabled (Tom Lane)
- Allow `ALTER DEFAULT PRIVILEGES` to operate on schemas without requiring CREATE permission (Tom Lane)
- Loosen restriction on keywords used in queries (Tom Lane)

  Specifically, lessen keyword restrictions for role names, language names, `EXPLAIN` and `COPY` options, and `SET` values. This allows `COPY ... (FORMAT BINARY)` to work as expected; previously `BINARY` needed to be quoted.
- Fix `pgp_pub_decrypt()` so it works for secret keys with passwords (Marko Kreen)
- Make pg_upgrade use `pg_dump --quote-all-identifiers` to avoid problems with keyword changes between releases (Tom Lane)
- Remove rare inaccurate warning during vacuum of index-less tables (Heikki Linnakangas)
- Ensure that `VACUUM ANALYZE` still runs the ANALYZE phase if its attempt to truncate the file is cancelled due to lock conflicts (Kevin Grittner)
- Avoid possible failure when performing transaction control commands (e.g `ROLLBACK`) in prepared queries (Tom Lane)
- Ensure that floating-point data input accepts standard spellings of "infinity" on all platforms (Tom Lane)

  The C99 standard says that allowable spellings are `inf`, `+inf`, `-inf`, `infinity`, `+infinity`, and `-infinity`. Make sure we recognize these even if the platform's `strtod` function doesn't.
- Expand ability to compare rows to records and arrays (Rafal Rzepecki, Tom Lane)
- Update time zone data files to tzdata release 2013d for DST law changes in Israel, Morocco, Palestine, and Paraguay. Also, historical zone data corrections for Macquarie Island.

E.27. Release 9.1.9

Release Date: 2013-04-04

This release contains a variety of fixes from 9.1.8. For information about new features in the 9.1 major release, see Section E.36.

E.27.1. Migration to Version 9.1.9

A dump/restore is not required for those running 9.1.X.

However, this release corrects several errors in management of GiST indexes. After installing this update, it is advisable to `REINDEX` any GiST indexes that meet one or more of the conditions described below.

Also, if you are upgrading from a version earlier than 9.1.6, see Section E.30.

E.27.2. Changes

- Fix insecure parsing of server command-line switches (Mitsumasa Kondo, Kyotaro Horiguchi)

  A connection request containing a database name that begins with "-" could be crafted to damage or destroy files within the server's data directory, even if the request is eventually rejected. (CVE-2013-1899)

- Reset OpenSSL randomness state in each postmaster child process (Marko Kreen)

  This avoids a scenario wherein random numbers generated by `contrib/pgcrypto` functions might be relatively easy for another database user to guess. The risk is only significant when the postmaster is configured with `ssl = on` but most connections don't use SSL encryption. (CVE-2013-1900)

- Make REPLICATION privilege checks test current user not authenticated user (Noah Misch)

  An unprivileged database user could exploit this mistake to call `pg_start_backup()` or `pg_stop_backup()`, thus possibly interfering with creation of routine backups. (CVE-2013-1901)

- Fix GiST indexes to not use "fuzzy" geometric comparisons when it's not appropriate to do so (Alexander Korotkov)

  The core geometric types perform comparisons using "fuzzy" equality, but `gist_box_same` must do exact comparisons, else GiST indexes using it might become inconsistent. After installing this update, users should `REINDEX` any GiST indexes on `box`, `polygon`, `circle`, or `point` columns, since all of these use `gist_box_same`.

- Fix erroneous range-union and penalty logic in GiST indexes that use `contrib/btree_gist` for variable-width data types, that is `text`, `bytea`, `bit`, and `numeric` columns (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in useless index bloat. Users are advised to `REINDEX` such indexes after installing this update.

- Fix bugs in GiST page splitting code for multi-column indexes (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in indexes that are unnecessarily inefficient to search. Users are advised to `REINDEX` multi-column GiST indexes after installing this update.

- Fix `gist_point_consistent` to handle fuzziness consistently (Alexander Korotkov)

  Index scans on GiST indexes on `point` columns would sometimes yield results different from a sequential scan, because `gist_point_consistent` disagreed with the underlying operator code about whether to do comparisons exactly or fuzzily.

- Fix buffer leak in WAL replay (Heikki Linnakangas)

  This bug could result in "incorrect local pin count" errors during replay, making recovery impossible.

- Fix race condition in `DELETE RETURNING` (Tom Lane)

  Under the right circumstances, `DELETE RETURNING` could attempt to fetch data from a shared buffer that the current process no longer has any pin on. If some other process changed the buffer meanwhile, this would lead to garbage `RETURNING` output, or even a crash.

- Fix infinite-loop risk in regular expression compilation (Tom Lane, Don Porter)

- Fix potential null-pointer dereference in regular expression compilation (Tom Lane)

- Fix `to_char()` to use ASCII-only case-folding rules where appropriate (Tom Lane)

  This fixes misbehavior of some template patterns that should be locale-independent, but mishandled "`I`" and "`i`" in Turkish locales.

- Fix unwanted rejection of timestamp `1999-12-31 24:00:00` (Tom Lane)

- Fix logic error when a single transaction does `UNLISTEN` then `LISTEN` (Tom Lane)

  The session wound up not listening for notify events at all, though it surely should listen in this case.

- Fix possible planner crash after columns have been added to a view that's depended on by another view (Tom Lane)

- Remove useless "picksplit doesn't support secondary split" log messages (Josh Hansen, Tom Lane)

  This message seems to have been added in expectation of code that was never written, and probably never will be, since GiST's default handling of secondary splits is actually pretty good. So stop nagging end users about it.

- Fix possible failure to send a session's last few transaction commit/abort counts to the statistics collector (Tom Lane)

- Eliminate memory leaks in PL/Perl's `spi_prepare()` function (Alex Hunsaker, Tom Lane)

- Fix pg_dumpall to handle database names containing "=" correctly (Heikki Linnakangas)

- Avoid crash in pg_dump when an incorrect connection string is given (Heikki Linnakangas)

- Ignore invalid indexes in pg_dump and pg_upgrade (Michael Paquier, Bruce Momjian)

  Dumping invalid indexes can cause problems at restore time, for example if the reason the index creation failed was because it tried to enforce a uniqueness condition not satisfied by the table's data. Also, if the index creation is in fact still in progress, it seems reasonable to consider it to be an uncommitted DDL change, which pg_dump wouldn't be expected to dump anyway. pg_upgrade now also skips invalid indexes rather than failing.

- In pg_basebackup, include only the current server version's subdirectory when backing up a tablespace (Heikki Linnakangas)

- Add a server version check in pg_basebackup and pg_receivexlog, so they fail cleanly with version combinations that won't work (Heikki Linnakangas)

- Fix `contrib/pg_trgm`'s `similarity()` function to return zero for trigram-less strings (Tom Lane)

  Previously it returned `NaN` due to internal division by zero.

- Update time zone data files to tzdata release 2013b for DST law changes in Chile, Haiti, Morocco, Paraguay, and some Russian areas. Also, historical zone data corrections for numerous places.

  Also, update the time zone abbreviation files for recent changes in Russia and elsewhere: `CHOT`, `GET`, `IRKT`, `KGT`, `KRAT`, `MAGT`, `MAWT`, `MSK`, `NOVT`, `OMST`, `TKT`, `VLAT`, `WST`, `YAKT`, `YEKT` now follow their current meanings, and `VOLT` (Europe/Volgograd) and `MIST` (Antarctica/Macquarie) are added to the default abbreviations list.

E.28. Release 9.1.8

Release Date: 2013-02-07

This release contains a variety of fixes from 9.1.7. For information about new features in the 9.1 major release, see Section E.36.

E.28.1. Migration to Version 9.1.8

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.6, see Section E.30.

E.28.2. Changes

- Prevent execution of `enum_recv` from SQL (Tom Lane)

  The function was misdeclared, allowing a simple SQL command to crash the server. In principle an attacker might be able to use it to examine the contents of server memory. Our thanks to Sumit Soni (via Secunia SVCRP) for reporting this issue. (CVE-2013-0255)

- Fix multiple problems in detection of when a consistent database state has been reached during WAL replay (Fujii Masao, Heikki Linnakangas, Simon Riggs, Andres Freund)

- Update minimum recovery point when truncating a relation file (Heikki Linnakangas)

  Once data has been discarded, it's no longer safe to stop recovery at an earlier point in the timeline.

- Fix recycling of WAL segments after changing recovery target timeline (Heikki Linnakangas)

- Fix missing cancellations in hot standby mode (Noah Misch, Simon Riggs)

  The need to cancel conflicting hot-standby queries would sometimes be missed, allowing those queries to see inconsistent data.

- Prevent recovery pause feature from pausing before users can connect (Tom Lane)

- Fix SQL grammar to allow subscripting or field selection from a sub-SELECT result (Tom Lane)

- Fix performance problems with autovacuum truncation in busy workloads (Jan Wieck)

  Truncation of empty pages at the end of a table requires exclusive lock, but autovacuum was coded to fail (and release the table lock) when there are conflicting lock requests. Under load, it is easily possible that truncation would never occur, resulting in table bloat. Fix by performing a partial truncation, releasing the lock, then attempting to re-acquire the lock and continue. This fix also greatly reduces the average time before autovacuum releases the lock after a conflicting request arrives.

- Protect against race conditions when scanning `pg_tablespace` (Stephen Frost, Tom Lane)

  `CREATE DATABASE` and `DROP DATABASE` could misbehave if there were concurrent updates of `pg_tablespace` entries.

- Prevent `DROP OWNED` from trying to drop whole databases or tablespaces (Álvaro Herrera)

  For safety, ownership of these objects must be reassigned, not dropped.

- Fix error in `vacuum_freeze_table_age` implementation (Andres Freund)

  In installations that have existed for more than `vacuum_freeze_min_age` transactions, this mistake prevented autovacuum from using partial-table scans, so that a full-table scan would always happen instead.

- Prevent misbehavior when a `RowExpr` or `XmlExpr` is parse-analyzed twice (Andres Freund, Tom Lane)

  This mistake could be user-visible in contexts such as `CREATE TABLE LIKE INCLUDING INDEXES`.

- Improve defenses against integer overflow in hashtable sizing calculations (Jeff Davis)
- Fix failure to ignore leftover temporary tables after a server crash (Tom Lane)
- Reject out-of-range dates in `to_date()` (Hitoshi Harada)
- Fix `pg_extension_config_dump()` to handle extension-update cases properly (Tom Lane)

  This function will now replace any existing entry for the target table, making it usable in extension update scripts.

- Fix PL/Python's handling of functions used as triggers on multiple tables (Andres Freund)
- Ensure that non-ASCII prompt strings are translated to the correct code page on Windows (Alexander Law, Noah Misch)

  This bug affected psql and some other client programs.

- Fix possible crash in psql's `\?` command when not connected to a database (Meng Qingzhong)
- Fix possible error if a relation file is removed while pg_basebackup is running (Heikki Linnakangas)
- Make pg_dump exclude data of unlogged tables when running on a hot-standby server (Magnus Hagander)

  This would fail anyway because the data is not available on the standby server, so it seems most convenient to assume `--no-unlogged-table-data` automatically.

- Fix pg_upgrade to deal with invalid indexes safely (Bruce Momjian)
- Fix one-byte buffer overrun in libpq's `PQprintTuples` (Xi Wang)

  This ancient function is not used anywhere by PostgreSQL itself, but it might still be used by some client code.

- Make ecpglib use translated messages properly (Chen Huajun)
- Properly install ecpg_compat and pgtypes libraries on MSVC (Jiang Guiqing)
- Include our version of `isinf()` in libecpg if it's not provided by the system (Jiang Guiqing)
- Rearrange configure's tests for supplied functions so it is not fooled by bogus exports from libedit/libreadline (Christoph Berg)
- Ensure Windows build number increases over time (Magnus Hagander)
- Make pgxs build executables with the right `.exe` suffix when cross-compiling for Windows (Zoltan Boszormenyi)
- Add new timezone abbreviation `FET` (Tom Lane)

  This is now used in some eastern-European time zones.

E.29. Release 9.1.7

Release Date: 2012-12-06

This release contains a variety of fixes from 9.1.6. For information about new features in the 9.1 major release, see Section E.36.

E.29.1. Migration to Version 9.1.7

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.6, see Section E.30.

E.29.2. Changes

- Fix multiple bugs associated with `CREATE INDEX CONCURRENTLY` (Andres Freund, Tom Lane)

  Fix `CREATE INDEX CONCURRENTLY` to use in-place updates when changing the state of an index's `pg_index` row. This prevents race conditions that could cause concurrent sessions to miss updating the target index, thus resulting in corrupt concurrently-created indexes.

  Also, fix various other operations to ensure that they ignore invalid indexes resulting from a failed `CREATE INDEX CONCURRENTLY` command. The most important of these is `VACUUM`, because an auto-vacuum could easily be launched on the table before corrective action can be taken to fix or remove the invalid index.

- Fix buffer locking during WAL replay (Tom Lane)

  The WAL replay code was insufficiently careful about locking buffers when replaying WAL records that affect more than one page. This could result in hot standby queries transiently seeing inconsistent states, resulting in wrong answers or unexpected failures.

- Fix an error in WAL generation logic for GIN indexes (Tom Lane)

  This could result in index corruption, if a torn-page failure occurred.

- Properly remove startup process's virtual XID lock when promoting a hot standby server to normal running (Simon Riggs)

  This oversight could prevent subsequent execution of certain operations such as `CREATE INDEX CONCURRENTLY`.

- Avoid bogus "out-of-sequence timeline ID" errors in standby mode (Heikki Linnakangas)

- Prevent the postmaster from launching new child processes after it's received a shutdown signal (Tom Lane)

  This mistake could result in shutdown taking longer than it should, or even never completing at all without additional user action.

- Avoid corruption of internal hash tables when out of memory (Hitoshi Harada)

- Prevent file descriptors for dropped tables from being held open past transaction end (Tom Lane)

  This should reduce problems with long-since-dropped tables continuing to occupy disk space.

- Prevent database-wide crash and restart when a new child process is unable to create a pipe for its latch (Tom Lane)

  Although the new process must fail, there is no good reason to force a database-wide restart, so avoid that. This improves robustness when the kernel is nearly out of file descriptors.

- Fix planning of non-strict equivalence clauses above outer joins (Tom Lane)

  The planner could derive incorrect constraints from a clause equating a non-strict construct to something else, for example `WHERE COALESCE(foo, 0) = 0` when `foo` is coming from the nullable side of an outer join.

- Fix `SELECT DISTINCT` with index-optimized `MIN`/`MAX` on an inheritance tree (Tom Lane)

  The planner would fail with "failed to re-find MinMaxAggInfo record" given this combination of factors.

- Improve planner's ability to prove exclusion constraints from equivalence classes (Tom Lane)

- Fix partial-row matching in hashed subplans to handle cross-type cases correctly (Tom Lane)

  This affects multicolumn `NOT IN` subplans, such as `WHERE (a, b) NOT IN (SELECT x, y FROM ...)` when for instance `b` and `y` are `int4` and `int8` respectively. This mistake led to wrong answers or crashes depending on the specific datatypes involved.

- Acquire buffer lock when re-fetching the old tuple for an `AFTER ROW UPDATE/DELETE` trigger (Andres Freund)

  In very unusual circumstances, this oversight could result in passing incorrect data to a trigger `WHEN` condition, or to the precheck logic for a foreign-key enforcement trigger. That could result in a crash, or in an incorrect decision about whether to fire the trigger.

- Fix `ALTER COLUMN TYPE` to handle inherited check constraints properly (Pavan Deolasee)

  This worked correctly in pre-8.4 releases, and now works correctly in 8.4 and later.

- Fix `ALTER EXTENSION SET SCHEMA`'s failure to move some subsidiary objects into the new schema (Álvaro Herrera, Dimitri Fontaine)

- Fix `REASSIGN OWNED` to handle grants on tablespaces (Álvaro Herrera)

- Ignore incorrect `pg_attribute` entries for system columns for views (Tom Lane)

  Views do not have any system columns. However, we forgot to remove such entries when converting a table to a view. That's fixed properly for 9.3 and later, but in previous branches we need to defend against existing mis-converted views.

- Fix rule printing to dump `INSERT INTO` *`table`* `DEFAULT VALUES` correctly (Tom Lane)

- Guard against stack overflow when there are too many `UNION`/`INTERSECT`/`EXCEPT` clauses in a query (Tom Lane)

- Prevent platform-dependent failures when dividing the minimum possible integer value by -1 (Xi Wang, Tom Lane)

- Fix possible access past end of string in date parsing (Hitoshi Harada)

- Fix failure to advance XID epoch if XID wraparound happens during a checkpoint and `wal_level` is `hot_standby` (Tom Lane, Andres Freund)

  While this mistake had no particular impact on PostgreSQL itself, it was bad for applications that rely on `txid_current()` and related functions: the TXID value would appear to go backwards.

- Fix display of `pg_stat_replication.sync_state` at a page boundary (Kyotaro Horiguchi)

- Produce an understandable error message if the length of the path name for a Unix-domain socket exceeds the platform-specific limit (Tom Lane, Andrew Dunstan)

  Formerly, this would result in something quite unhelpful, such as "Non-recoverable failure in name resolution".

- Fix memory leaks when sending composite column values to the client (Tom Lane)

- Make pg_ctl more robust about reading the `postmaster.pid` file (Heikki Linnakangas)

  Fix race conditions and possible file descriptor leakage.

- Fix possible crash in psql if incorrectly-encoded data is presented and the `client_encoding` setting is a client-only encoding, such as SJIS (Jiang Guiqing)

- Make pg_dump dump `SEQUENCE SET` items in the data not pre-data section of the archive (Tom Lane)

  This change fixes dumping of sequences that are marked as extension configuration tables.

- Fix bugs in the `restore.sql` script emitted by pg_dump in `tar` output format (Tom Lane)

  The script would fail outright on tables whose names include upper-case characters. Also, make the script capable of restoring data in `--inserts` mode as well as the regular COPY mode.

- Fix pg_restore to accept POSIX-conformant `tar` files (Brian Weaver, Tom Lane)

  The original coding of pg_dump's `tar` output mode produced files that are not fully conformant with the POSIX standard. This has been corrected for version 9.3. This patch updates previous branches so that they will accept both the incorrect and the corrected formats, in hopes of avoiding compatibility problems when 9.3 comes out.

- Fix `tar` files emitted by pg_basebackup to be POSIX conformant (Brian Weaver, Tom Lane)

- Fix pg_resetxlog to locate `postmaster.pid` correctly when given a relative path to the data directory (Tom Lane)

  This mistake could lead to pg_resetxlog not noticing that there is an active postmaster using the data directory.

- Fix libpq's `lo_import()` and `lo_export()` functions to report file I/O errors properly (Tom Lane)

- Fix ecpg's processing of nested structure pointer variables (Muhammad Usama)

- Fix ecpg's `ecpg_get_data` function to handle arrays properly (Michael Meskes)

- Make `contrib/pageinspect`'s btree page inspection functions take buffer locks while examining pages (Tom Lane)

- Ensure that `make install` for an extension creates the `extension` installation directory (Cédric Villemain)

  Previously, this step was missed if `MODULEDIR` was set in the extension's Makefile.

- Fix pgxs support for building loadable modules on AIX (Tom Lane)

  Building modules outside the original source tree didn't work on AIX.

- Update time zone data files to tzdata release 2012j for DST law changes in Cuba, Israel, Jordan, Libya, Palestine, Western Samoa, and portions of Brazil.

E.30. Release 9.1.6

Release Date: 2012-09-24

This release contains a variety of fixes from 9.1.5. For information about new features in the 9.1 major release, see Section E.36.

E.30.1. Migration to Version 9.1.6

A dump/restore is not required for those running 9.1.X.

However, you may need to perform REINDEX operations to recover from the effects of the data corruption bug described in the first changelog item below.

Also, if you are upgrading from a version earlier than 9.1.4, see Section E.32.

E.30.2. Changes

- Fix persistence marking of shared buffers during WAL replay (Jeff Davis)

  This mistake can result in buffers not being written out during checkpoints, resulting in data corruption if the server later crashes without ever having written those buffers. Corruption can occur on any server following crash recovery, but it is significantly more likely to occur on standby slave servers since those perform much more WAL replay. There is a low probability of corruption of btree and GIN indexes. There is a much higher probability of corruption of table "visibility maps". Fortunately, visibility maps are non-critical data in 9.1, so the worst consequence of such corruption in 9.1 installations is transient inefficiency of vacuuming. Table data proper cannot be corrupted by this bug.

  While no index corruption due to this bug is known to have occurred in the field, as a precautionary measure it is recommended that production installations REINDEX all btree and GIN indexes at a convenient time after upgrading to 9.1.6.

  Also, if you intend to do an in-place upgrade to 9.2.X, before doing so it is recommended to perform a VACUUM of all tables while having vacuum_freeze_table_age set to zero. This will ensure that any lingering wrong data in the visibility maps is corrected before 9.2.X can depend on it. vacuum_cost_delay can be adjusted to reduce the performance impact of vacuuming, while causing it to take longer to finish.

- Fix planner's assignment of executor parameters, and fix executor's rescan logic for CTE plan nodes (Tom Lane)

  These errors could result in wrong answers from queries that scan the same WITH subquery multiple times.

- Fix misbehavior when default_transaction_isolation is set to serializable (Kevin Grittner, Tom Lane, Heikki Linnakangas)

  Symptoms include crashes at process start on Windows, and crashes in hot standby operation.

- Improve selectivity estimation for text search queries involving prefixes, i.e. *word*:* patterns (Tom Lane)

- Improve page-splitting decisions in GiST indexes (Alexander Korotkov, Robert Haas, Tom Lane)

  Multi-column GiST indexes might suffer unexpected bloat due to this error.

- Fix cascading privilege revoke to stop if privileges are still held (Tom Lane)

  If we revoke a grant option from some role *X*, but *X* still holds that option via a grant from someone else, we should not recursively revoke the corresponding privilege from role(s) *Y* that *X* had granted it to.

- Disallow extensions from containing the schema they are assigned to (Thom Brown)

  This situation creates circular dependencies that confuse pg_dump and probably other things. It's confusing for humans too, so disallow it.

- Improve error messages for Hot Standby misconfiguration errors (Gurjeet Singh)
- Make configure probe for `mbstowcs_l` (Tom Lane)

  This fixes build failures on some versions of AIX.
- Fix handling of `SIGFPE` when PL/Perl is in use (Andres Freund)

  Perl resets the process's `SIGFPE` handler to `SIG_IGN`, which could result in crashes later on. Restore the normal Postgres signal handler after initializing PL/Perl.
- Prevent PL/Perl from crashing if a recursive PL/Perl function is redefined while being executed (Tom Lane)
- Work around possible misoptimization in PL/Perl (Tom Lane)

  Some Linux distributions contain an incorrect version of `pthread.h` that results in incorrect compiled code in PL/Perl, leading to crashes if a PL/Perl function calls another one that throws an error.
- Fix bugs in `contrib/pg_trgm`'s `LIKE` pattern analysis code (Fujii Masao)

  `LIKE` queries using a trigram index could produce wrong results if the pattern contained `LIKE` escape characters.
- Fix pg_upgrade's handling of line endings on Windows (Andrew Dunstan)

  Previously, pg_upgrade might add or remove carriage returns in places such as function bodies.
- On Windows, make pg_upgrade use backslash path separators in the scripts it emits (Andrew Dunstan)
- Remove unnecessary dependency on pg_config from pg_upgrade (Peter Eisentraut)
- Update time zone data files to tzdata release 2012f for DST law changes in Fiji

E.31. Release 9.1.5

Release Date: 2012-08-17

This release contains a variety of fixes from 9.1.4. For information about new features in the 9.1 major release, see Section E.36.

E.31.1. Migration to Version 9.1.5

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.4, see Section E.32.

E.31.2. Changes

- Prevent access to external files/URLs via XML entity references (Noah Misch, Tom Lane)

  `xml_parse()` would attempt to fetch external files or URLs as needed to resolve DTD and entity references in an XML value, thus allowing unprivileged database users to attempt to fetch data with

the privileges of the database server. While the external data wouldn't get returned directly to the user, portions of it could be exposed in error messages if the data didn't parse as valid XML; and in any case the mere ability to check existence of a file might be useful to an attacker. (CVE-2012-3489)

- Prevent access to external files/URLs via `contrib/xml2`'s `xslt_process()` (Peter Eisentraut)

  libxslt offers the ability to read and write both files and URLs through stylesheet commands, thus allowing unprivileged database users to both read and write data with the privileges of the database server. Disable that through proper use of libxslt's security options. (CVE-2012-3488)

  Also, remove `xslt_process()`'s ability to fetch documents and stylesheets from external files/URLs. While this was a documented "feature", it was long regarded as a bad idea. The fix for CVE-2012-3489 broke that capability, and rather than expend effort on trying to fix it, we're just going to summarily remove it.

- Prevent too-early recycling of btree index pages (Noah Misch)

  When we allowed read-only transactions to skip assigning XIDs, we introduced the possibility that a deleted btree page could be recycled while a read-only transaction was still in flight to it. This would result in incorrect index search results. The probability of such an error occurring in the field seems very low because of the timing requirements, but nonetheless it should be fixed.

- Fix crash-safety bug with newly-created-or-reset sequences (Tom Lane)

  If `ALTER SEQUENCE` was executed on a freshly created or reset sequence, and then precisely one `nextval()` call was made on it, and then the server crashed, WAL replay would restore the sequence to a state in which it appeared that no `nextval()` had been done, thus allowing the first sequence value to be returned again by the next `nextval()` call. In particular this could manifest for `serial` columns, since creation of a serial column's sequence includes an `ALTER SEQUENCE OWNED BY` step.

- Fix race condition in `enum`-type value comparisons (Robert Haas, Tom Lane)

  Comparisons could fail when encountering an enum value added since the current query started.

- Fix `txid_current()` to report the correct epoch when not in hot standby (Heikki Linnakangas)

  This fixes a regression introduced in the previous minor release.

- Prevent selection of unsuitable replication connections as the synchronous standby (Fujii Masao)

  The master might improperly choose pseudo-servers such as pg_receivexlog or pg_basebackup as the synchronous standby, and then wait indefinitely for them.

- Fix bug in startup of Hot Standby when a master transaction has many subtransactions (Andres Freund)

  This mistake led to failures reported as "out-of-order XID insertion in KnownAssignedXids".

- Ensure the `backup_label` file is fsync'd after `pg_start_backup()` (Dave Kerr)

- Fix timeout handling in walsender processes (Tom Lane)

  WAL sender background processes neglected to establish a SIGALRM handler, meaning they would wait forever in some corner cases where a timeout ought to happen.

- Wake walsenders after each background flush by walwriter (Andres Freund, Simon Riggs)

  This greatly reduces replication delay when the workload contains only asynchronously-committed transactions.

- Fix `LISTEN`/`NOTIFY` to cope better with I/O problems, such as out of disk space (Tom Lane)

After a write failure, all subsequent attempts to send more NOTIFY messages would fail with messages like "Could not read from file "pg_notify/*nnnn*" at offset *nnnnn*: Success".

- Only allow autovacuum to be auto-canceled by a directly blocked process (Tom Lane)

  The original coding could allow inconsistent behavior in some cases; in particular, an autovacuum could get canceled after less than deadlock_timeout grace period.

- Improve logging of autovacuum cancels (Robert Haas)

- Fix log collector so that log_truncate_on_rotation works during the very first log rotation after server start (Tom Lane)

- Fix WITH attached to a nested set operation (UNION/INTERSECT/EXCEPT) (Tom Lane)

- Ensure that a whole-row reference to a subquery doesn't include any extra GROUP BY or ORDER BY columns (Tom Lane)

- Fix dependencies generated during ALTER TABLE ... ADD CONSTRAINT USING INDEX (Tom Lane)

  This command left behind a redundant pg_depend entry for the index, which could confuse later operations, notably ALTER TABLE ... ALTER COLUMN TYPE on one of the indexed columns.

- Fix REASSIGN OWNED to work on extensions (Alvaro Herrera)

- Disallow copying whole-row references in CHECK constraints and index definitions during CREATE TABLE (Tom Lane)

  This situation can arise in CREATE TABLE with LIKE or INHERITS. The copied whole-row variable was incorrectly labeled with the row type of the original table not the new one. Rejecting the case seems reasonable for LIKE, since the row types might well diverge later. For INHERITS we should ideally allow it, with an implicit coercion to the parent table's row type; but that will require more work than seems safe to back-patch.

- Fix memory leak in ARRAY(SELECT ...) subqueries (Heikki Linnakangas, Tom Lane)

- Fix planner to pass correct collation to operator selectivity estimators (Tom Lane)

  This was not previously required by any core selectivity estimation function, but third-party code might need it.

- Fix extraction of common prefixes from regular expressions (Tom Lane)

  The code could get confused by quantified parenthesized subexpressions, such as ^(foo)?bar. This would lead to incorrect index optimization of searches for such patterns.

- Fix bugs with parsing signed *hh*:*mm* and *hh*:*mm*:*ss* fields in interval constants (Amit Kapila, Tom Lane)

- Fix pg_dump to better handle views containing partial GROUP BY lists (Tom Lane)

  A view that lists only a primary key column in GROUP BY, but uses other table columns as if they were grouped, gets marked as depending on the primary key. Improper handling of such primary key dependencies in pg_dump resulted in poorly-ordered dumps, which at best would be inefficient to restore and at worst could result in outright failure of a parallel pg_restore run.

- In PL/Perl, avoid setting UTF8 flag when in SQL_ASCII encoding (Alex Hunsaker, Kyotaro Horiguchi, Alvaro Herrera)

- Use Postgres' encoding conversion functions, not Python's, when converting a Python Unicode string to the server encoding in PL/Python (Jan Urbanski)

  This avoids some corner-case problems, notably that Python doesn't support all the encodings Postgres does. A notable functional change is that if the server encoding is SQL_ASCII, you will

get the UTF-8 representation of the string; formerly, any non-ASCII characters in the string would result in an error.

- Fix mapping of PostgreSQL encodings to Python encodings in PL/Python (Jan Urbanski)
- Report errors properly in `contrib/xml2`'s `xslt_process()` (Tom Lane)
- Update time zone data files to tzdata release 2012e for DST law changes in Morocco and Tokelau

E.32. Release 9.1.4

Release Date: 2012-06-04

This release contains a variety of fixes from 9.1.3. For information about new features in the 9.1 major release, see Section E.36.

E.32.1. Migration to Version 9.1.4

A dump/restore is not required for those running 9.1.X.

However, if you use the `citext` data type, and you upgraded from a previous major release by running pg_upgrade, you should run `CREATE EXTENSION citext FROM unpackaged` to avoid collation-related failures in `citext` operations. The same is necessary if you restore a dump from a pre-9.1 database that contains an instance of the `citext` data type. If you've already run the `CREATE EXTENSION` command before upgrading to 9.1.4, you will instead need to do manual catalog updates as explained in the third changelog item below.

Also, if you are upgrading from a version earlier than 9.1.2, see Section E.34.

E.32.2. Changes

- Fix incorrect password transformation in `contrib/pgcrypto`'s DES `crypt()` function (Solar Designer)

  If a password string contained the byte value `0x80`, the remainder of the password was ignored, causing the password to be much weaker than it appeared. With this fix, the rest of the string is properly included in the DES hash. Any stored password values that are affected by this bug will thus no longer match, so the stored values may need to be updated. (CVE-2012-2143)

- Ignore `SECURITY DEFINER` and `SET` attributes for a procedural language's call handler (Tom Lane)

  Applying such attributes to a call handler could crash the server. (CVE-2012-2655)

- Make `contrib/citext`'s upgrade script fix collations of `citext` arrays and domains over `citext` (Tom Lane)

  Release 9.1.2 provided a fix for collations of `citext` columns and indexes in databases upgraded or reloaded from pre-9.1 installations, but that fix was incomplete: it neglected to handle arrays and domains over `citext`. This release extends the module's upgrade script to handle these cases. As

before, if you have already run the upgrade script, you'll need to run the collation update commands by hand instead. See the 9.1.2 release notes for more information about doing this.

- Allow numeric timezone offsets in `timestamp` input to be up to 16 hours away from UTC (Tom Lane)

  Some historical time zones have offsets larger than 15 hours, the previous limit. This could result in dumped data values being rejected during reload.

- Fix timestamp conversion to cope when the given time is exactly the last DST transition time for the current timezone (Tom Lane)

  This oversight has been there a long time, but was not noticed previously because most DST-using zones are presumed to have an indefinite sequence of future DST transitions.

- Fix `text` to `name` and `char` to `name` casts to perform string truncation correctly in multibyte encodings (Karl Schnaitter)

- Fix memory copying bug in `to_tsquery()` (Heikki Linnakangas)

- Ensure `txid_current()` reports the correct epoch when executed in hot standby (Simon Riggs)

- Fix planner's handling of outer PlaceHolderVars within subqueries (Tom Lane)

  This bug concerns sub-SELECTs that reference variables coming from the nullable side of an outer join of the surrounding query. In 9.1, queries affected by this bug would fail with "ERROR: Upper-level PlaceHolderVar found where not expected". But in 9.0 and 8.4, you'd silently get possibly-wrong answers, since the value transmitted into the subquery wouldn't go to null when it should.

- Fix planning of `UNION ALL` subqueries with output columns that are not simple variables (Tom Lane)

  Planning of such cases got noticeably worse in 9.1 as a result of a misguided fix for "MergeAppend child's targetlist doesn't match MergeAppend" errors. Revert that fix and do it another way.

- Fix slow session startup when `pg_attribute` is very large (Tom Lane)

  If `pg_attribute` exceeds one-fourth of `shared_buffers`, cache rebuilding code that is sometimes needed during session start would trigger the synchronized-scan logic, causing it to take many times longer than normal. The problem was particularly acute if many new sessions were starting at once.

- Ensure sequential scans check for query cancel reasonably often (Merlin Moncure)

  A scan encountering many consecutive pages that contain no live tuples would not respond to interrupts meanwhile.

- Ensure the Windows implementation of `PGSemaphoreLock()` clears `ImmediateInterruptOK` before returning (Tom Lane)

  This oversight meant that a query-cancel interrupt received later in the same query could be accepted at an unsafe time, with unpredictable but not good consequences.

- Show whole-row variables safely when printing views or rules (Abbas Butt, Tom Lane)

  Corner cases involving ambiguous names (that is, the name could be either a table or column name of the query) were printed in an ambiguous way, risking that the view or rule would be interpreted differently after dump and reload. Avoid the ambiguous case by attaching a no-op cast.

- Fix `COPY FROM` to properly handle null marker strings that correspond to invalid encoding (Tom Lane)

A null marker string such as `E'\\0'` should work, and did work in the past, but the case got broken in 8.4.

- Fix `EXPLAIN VERBOSE` for writable CTEs containing `RETURNING` clauses (Tom Lane)
- Fix `PREPARE TRANSACTION` to work correctly in the presence of advisory locks (Tom Lane)

  Historically, `PREPARE TRANSACTION` has simply ignored any session-level advisory locks the session holds, but this case was accidentally broken in 9.1.
- Fix truncation of unlogged tables (Robert Haas)
- Ignore missing schemas during non-interactive assignments of `search_path` (Tom Lane)

  This re-aligns 9.1's behavior with that of older branches. Previously 9.1 would throw an error for nonexistent schemas mentioned in `search_path` settings obtained from places such as `ALTER DATABASE SET`.
- Fix bugs with temporary or transient tables used in extension scripts (Tom Lane)

  This includes cases such as a rewriting `ALTER TABLE` within an extension update script, since that uses a transient table behind the scenes.
- Ensure autovacuum worker processes perform stack depth checking properly (Heikki Linnakangas)

  Previously, infinite recursion in a function invoked by auto-`ANALYZE` could crash worker processes.
- Fix logging collector to not lose log coherency under high load (Andrew Dunstan)

  The collector previously could fail to reassemble large messages if it got too busy.
- Fix logging collector to ensure it will restart file rotation after receiving SIGHUP (Tom Lane)
- Fix "too many LWLocks taken" failure in GiST indexes (Heikki Linnakangas)
- Fix WAL replay logic for GIN indexes to not fail if the index was subsequently dropped (Tom Lane)
- Correctly detect SSI conflicts of prepared transactions after a crash (Dan Ports)
- Avoid synchronous replication delay when committing a transaction that only modified temporary tables (Heikki Linnakangas)

  In such a case the transaction's commit record need not be flushed to standby servers, but some of the code didn't know that and waited for it to happen anyway.
- Fix error handling in pg_basebackup (Thomas Ogrisegg, Fujii Masao)
- Fix walsender to not go into a busy loop if connection is terminated (Fujii Masao)
- Fix memory leak in PL/pgSQL's `RETURN NEXT` command (Joe Conway)
- Fix PL/pgSQL's `GET DIAGNOSTICS` command when the target is the function's first variable (Tom Lane)
- Ensure that PL/Perl package-qualifies the `_TD` variable (Alex Hunsaker)

  This bug caused trigger invocations to fail when they are nested within a function invocation that changes the current package.
- Fix PL/Python functions returning composite types to accept a string for their result value (Jan Urbanski)

  This case was accidentally broken by the 9.1 additions to allow a composite result value to be supplied in other formats, such as dictionaries.
- Fix potential access off the end of memory in psql's expanded display (`\x`) mode (Peter Eisentraut)

- Fix several performance problems in pg_dump when the database contains many objects (Jeff Janes, Tom Lane)

  pg_dump could get very slow if the database contained many schemas, or if many objects are in dependency loops, or if there are many owned sequences.

- Fix memory and file descriptor leaks in pg_restore when reading a directory-format archive (Peter Eisentraut)
- Fix pg_upgrade for the case that a database stored in a non-default tablespace contains a table in the cluster's default tablespace (Bruce Momjian)
- In ecpg, fix rare memory leaks and possible overwrite of one byte after the `sqlca_t` structure (Peter Eisentraut)
- Fix `contrib/dblink`'s `dblink_exec()` to not leak temporary database connections upon error (Tom Lane)
- Fix `contrib/dblink` to report the correct connection name in error messages (Kyotaro Horiguchi)
- Fix `contrib/vacuumlo` to use multiple transactions when dropping many large objects (Tim Lewis, Robert Haas, Tom Lane)

  This change avoids exceeding `max_locks_per_transaction` when many objects need to be dropped. The behavior can be adjusted with the new `-l` (limit) option.

- Update time zone data files to tzdata release 2012c for DST law changes in Antarctica, Armenia, Chile, Cuba, Falkland Islands, Gaza, Haiti, Hebron, Morocco, Syria, and Tokelau Islands; also historical corrections for Canada.

E.33. Release 9.1.3

Release Date: 2012-02-27

This release contains a variety of fixes from 9.1.2. For information about new features in the 9.1 major release, see Section E.36.

E.33.1. Migration to Version 9.1.3

A dump/restore is not required for those running 9.1.X.

However, if you are upgrading from a version earlier than 9.1.2, see Section E.34.

E.33.2. Changes

- Require execute permission on the trigger function for `CREATE TRIGGER` (Robert Haas)

  This missing check could allow another user to execute a trigger function with forged input data, by installing it on a table he owns. This is only of significance for trigger functions marked `SECURITY DEFINER`, since otherwise trigger functions run as the table owner anyway. (CVE-2012-0866)

- Remove arbitrary limitation on length of common name in SSL certificates (Heikki Linnakangas)

  Both libpq and the server truncated the common name extracted from an SSL certificate at 32 bytes. Normally this would cause nothing worse than an unexpected verification failure, but there are some rather-implausible scenarios in which it might allow one certificate holder to impersonate another. The victim would have to have a common name exactly 32 bytes long, and the attacker would have to persuade a trusted CA to issue a certificate in which the common name has that string as a prefix. Impersonating a server would also require some additional exploit to redirect client connections. (CVE-2012-0867)

- Convert newlines to spaces in names written in pg_dump comments (Robert Haas)

  pg_dump was incautious about sanitizing object names that are emitted within SQL comments in its output script. A name containing a newline would at least render the script syntactically incorrect. Maliciously crafted object names could present a SQL injection risk when the script is reloaded. (CVE-2012-0868)

- Fix btree index corruption from insertions concurrent with vacuuming (Tom Lane)

  An index page split caused by an insertion could sometimes cause a concurrently-running `VACUUM` to miss removing index entries that it should remove. After the corresponding table rows are removed, the dangling index entries would cause errors (such as "could not read block N in file ...") or worse, silently wrong query results after unrelated rows are re-inserted at the now-free table locations. This bug has been present since release 8.2, but occurs so infrequently that it was not diagnosed until now. If you have reason to suspect that it has happened in your database, reindexing the affected index will fix things.

- Fix transient zeroing of shared buffers during WAL replay (Tom Lane)

  The replay logic would sometimes zero and refill a shared buffer, so that the contents were transiently invalid. In hot standby mode this can result in a query that's executing in parallel seeing garbage data. Various symptoms could result from that, but the most common one seems to be "invalid memory alloc request size".

- Fix handling of data-modifying `WITH` subplans in `READ COMMITTED` rechecking (Tom Lane)

  A `WITH` clause containing `INSERT`/`UPDATE`/`DELETE` would crash if the parent `UPDATE` or `DELETE` command needed to be re-evaluated at one or more rows due to concurrent updates in `READ COMMITTED` mode.

- Fix corner case in SSI transaction cleanup (Dan Ports)

  When finishing up a read-write serializable transaction, a crash could occur if all remaining active serializable transactions are read-only.

- Fix postmaster to attempt restart after a hot-standby crash (Tom Lane)

  A logic error caused the postmaster to terminate, rather than attempt to restart the cluster, if any backend process crashed while operating in hot standby mode.

- Fix `CLUSTER`/`VACUUM FULL` handling of toast values owned by recently-updated rows (Tom Lane)

  This oversight could lead to "duplicate key value violates unique constraint" errors being reported against the toast table's index during one of these commands.

- Update per-column permissions, not only per-table permissions, when changing table owner (Tom Lane)

  Failure to do this meant that any previously granted column permissions were still shown as having been granted by the old owner. This meant that neither the new owner nor a superuser could revoke the now-untraceable-to-table-owner permissions.

- Support foreign data wrappers and foreign servers in `REASSIGN OWNED` (Alvaro Herrera)

This command failed with "unexpected classid" errors if it needed to change the ownership of any such objects.

- Allow non-existent values for some settings in `ALTER USER/DATABASE SET` (Heikki Linnakangas)

  Allow `default_text_search_config`, `default_tablespace`, and `temp_tablespaces` to be set to names that are not known. This is because they might be known in another database where the setting is intended to be used, or for the tablespace cases because the tablespace might not be created yet. The same issue was previously recognized for `search_path`, and these settings now act like that one.

- Fix "unsupported node type" error caused by `COLLATE` in an `INSERT` expression (Tom Lane)

- Avoid crashing when we have problems deleting table files post-commit (Tom Lane)

  Dropping a table should lead to deleting the underlying disk files only after the transaction commits. In event of failure then (for instance, because of wrong file permissions) the code is supposed to just emit a warning message and go on, since it's too late to abort the transaction. This logic got broken as of release 8.4, causing such situations to result in a PANIC and an unrestartable database.

- Recover from errors occurring during WAL replay of `DROP TABLESPACE` (Tom Lane)

  Replay will attempt to remove the tablespace's directories, but there are various reasons why this might fail (for example, incorrect ownership or permissions on those directories). Formerly the replay code would panic, rendering the database unrestartable without manual intervention. It seems better to log the problem and continue, since the only consequence of failure to remove the directories is some wasted disk space.

- Fix race condition in logging AccessExclusiveLocks for hot standby (Simon Riggs)

  Sometimes a lock would be logged as being held by "transaction zero". This is at least known to produce assertion failures on slave servers, and might be the cause of more serious problems.

- Track the OID counter correctly during WAL replay, even when it wraps around (Tom Lane)

  Previously the OID counter would remain stuck at a high value until the system exited replay mode. The practical consequences of that are usually nil, but there are scenarios wherein a standby server that's been promoted to master might take a long time to advance the OID counter to a reasonable value once values are needed.

- Prevent emitting misleading "consistent recovery state reached" log message at the beginning of crash recovery (Heikki Linnakangas)

- Fix initial value of `pg_stat_replication.replay_location` (Fujii Masao)

  Previously, the value shown would be wrong until at least one WAL record had been replayed.

- Fix regular expression back-references with $*$ attached (Tom Lane)

  Rather than enforcing an exact string match, the code would effectively accept any string that satisfies the pattern sub-expression referenced by the back-reference symbol.

  A similar problem still afflicts back-references that are embedded in a larger quantified expression, rather than being the immediate subject of the quantifier. This will be addressed in a future PostgreSQL release.

- Fix recently-introduced memory leak in processing of `inet`/`cidr` values (Heikki Linnakangas)

  A patch in the December 2011 releases of PostgreSQL caused memory leakage in these operations, which could be significant in scenarios such as building a btree index on such a column.

- Fix planner's ability to push down index-expression restrictions through `UNION ALL` (Tom Lane)

This type of optimization was inadvertently disabled by a fix for another problem in 9.1.2.

- Fix planning of `WITH` clauses referenced in `UPDATE`/`DELETE` on an inherited table (Tom Lane)

  This bug led to "could not find plan for CTE" failures.

- Fix GIN cost estimation to handle `column IN (...)` index conditions (Marti Raudsepp)

  This oversight would usually lead to crashes if such a condition could be used with a GIN index.

- Prevent assertion failure when exiting a session with an open, failed transaction (Tom Lane)

  This bug has no impact on normal builds with asserts not enabled.

- Fix dangling pointer after `CREATE TABLE AS`/`SELECT INTO` in a SQL-language function (Tom Lane)

  In most cases this only led to an assertion failure in assert-enabled builds, but worse consequences seem possible.

- Avoid double close of file handle in syslogger on Windows (MauMau)

  Ordinarily this error was invisible, but it would cause an exception when running on a debug version of Windows.

- Fix I/O-conversion-related memory leaks in plpgsql (Andres Freund, Jan Urbanski, Tom Lane)

  Certain operations would leak memory until the end of the current function.

- Work around bug in perl's SvPVutf8() function (Andrew Dunstan)

  This function crashes when handed a typeglob or certain read-only objects such as `$^V`. Make plperl avoid passing those to it.

- In pg_dump, don't dump contents of an extension's configuration tables if the extension itself is not being dumped (Tom Lane)

- Improve pg_dump's handling of inherited table columns (Tom Lane)

  pg_dump mishandled situations where a child column has a different default expression than its parent column. If the default is textually identical to the parent's default, but not actually the same (for instance, because of schema search path differences) it would not be recognized as different, so that after dump and restore the child would be allowed to inherit the parent's default. Child columns that are `NOT NULL` where their parent is not could also be restored subtly incorrectly.

- Fix pg_restore's direct-to-database mode for INSERT-style table data (Tom Lane)

  Direct-to-database restores from archive files made with `--inserts` or `--column-inserts` options fail when using pg_restore from a release dated September or December 2011, as a result of an oversight in a fix for another problem. The archive file itself is not at fault, and text-mode output is okay.

- Teach pg_upgrade to handle renaming of plpython's shared library (Bruce Momjian)

  Upgrading a pre-9.1 database that included plpython would fail because of this oversight.

- Allow pg_upgrade to process tables containing `regclass` columns (Bruce Momjian)

  Since pg_upgrade now takes care to preserve `pg_class` OIDs, there was no longer any reason for this restriction.

- Make libpq ignore `ENOTDIR` errors when looking for an SSL client certificate file (Magnus Hagander)

  This allows SSL connections to be established, though without a certificate, even when the user's home directory is set to something like `/dev/null`.

- Fix some more field alignment issues in ecpg's SQLDA area (Zoltan Boszormenyi)

- Allow `AT` option in ecpg `DEALLOCATE` statements (Michael Meskes)

  The infrastructure to support this has been there for awhile, but through an oversight there was still an error check rejecting the case.

- Do not use the variable name when defining a varchar structure in ecpg (Michael Meskes)

- Fix `contrib/auto_explain`'s JSON output mode to produce valid JSON (Andrew Dunstan)

  The output used brackets at the top level, when it should have used braces.

- Fix error in `contrib/intarray`'s `int[] & int[]` operator (Guillaume Lelarge)

  If the smallest integer the two input arrays have in common is 1, and there are smaller values in either array, then 1 would be incorrectly omitted from the result.

- Fix error detection in `contrib/pgcrypto`'s `encrypt_iv()` and `decrypt_iv()` (Marko Kreen)

  These functions failed to report certain types of invalid-input errors, and would instead return random garbage values for incorrect input.

- Fix one-byte buffer overrun in `contrib/test_parser` (Paul Guyot)

  The code would try to read one more byte than it should, which would crash in corner cases. Since `contrib/test_parser` is only example code, this is not a security issue in itself, but bad example code is still bad.

- Use `__sync_lock_test_and_set()` for spinlocks on ARM, if available (Martin Pitt)

  This function replaces our previous use of the `SWPB` instruction, which is deprecated and not available on ARMv6 and later. Reports suggest that the old code doesn't fail in an obvious way on recent ARM boards, but simply doesn't interlock concurrent accesses, leading to bizarre failures in multiprocess operation.

- Use `-fexcess-precision=standard` option when building with gcc versions that accept it (Andrew Dunstan)

  This prevents assorted scenarios wherein recent versions of gcc will produce creative results.

- Allow use of threaded Python on FreeBSD (Chris Rees)

  Our configure script previously believed that this combination wouldn't work; but FreeBSD fixed the problem, so remove that error check.

- Allow MinGW builds to use standardly-named OpenSSL libraries (Tomasz Ostrowski)

E.34. Release 9.1.2

Release Date: 2011-12-05

This release contains a variety of fixes from 9.1.1. For information about new features in the 9.1 major release, see Section E.36.

E.34.1. Migration to Version 9.1.2

A dump/restore is not required for those running 9.1.X.

However, a longstanding error was discovered in the definition of the `information_schema.referential_constraints` view. If you rely on correct results from that view, you should replace its definition as explained in the first changelog item below.

Also, if you use the `citext` data type, and you upgraded from a previous major release by running pg_upgrade, you should run `CREATE EXTENSION citext FROM unpackaged` to avoid collation-related failures in `citext` operations. The same is necessary if you restore a dump from a pre-9.1 database that contains an instance of the `citext` data type. If you've already run the `CREATE EXTENSION` command before upgrading to 9.1.2, you will instead need to do manual catalog updates as explained in the second changelog item.

E.34.2. Changes

- Fix bugs in `information_schema.referential_constraints` view (Tom Lane)

  This view was being insufficiently careful about matching the foreign-key constraint to the depended-on primary or unique key constraint. That could result in failure to show a foreign key constraint at all, or showing it multiple times, or claiming that it depends on a different constraint than the one it really does.

  Since the view definition is installed by initdb, merely upgrading will not fix the problem. If you need to fix this in an existing installation, you can (as a superuser) drop the `information_schema` schema then re-create it by sourcing *`SHAREDIR`*`/information_schema.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) This must be repeated in each database to be fixed.

- Make `contrib/citext`'s upgrade script fix collations of `citext` columns and indexes (Tom Lane)

  Existing `citext` columns and indexes aren't correctly marked as being of a collatable data type during pg_upgrade from a pre-9.1 server, or when a pre-9.1 dump containing the `citext` type is loaded into a 9.1 server. That leads to operations on these columns failing with errors such as "could not determine which collation to use for string comparison". This change allows them to be fixed by the same script that upgrades the `citext` module into a proper 9.1 extension during `CREATE EXTENSION citext FROM unpackaged`.

  If you have a previously-upgraded database that is suffering from this problem, and you already ran the `CREATE EXTENSION` command, you can manually run (as superuser) the `UPDATE` commands found at the end of *`SHAREDIR`*`/extension/citext--unpackaged--1.0.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) There is no harm in doing this again if unsure.

- Fix possible crash during `UPDATE` or `DELETE` that joins to the output of a scalar-returning function (Tom Lane)

  A crash could only occur if the target row had been concurrently updated, so this problem surfaced only intermittently.

- Fix incorrect replay of WAL records for GIN index updates (Tom Lane)

  This could result in transiently failing to find index entries after a crash, or on a hot-standby server. The problem would be repaired by the next `VACUUM` of the index, however.

- Fix TOAST-related data corruption during `CREATE TABLE dest AS SELECT * FROM src` or `INSERT INTO dest SELECT * FROM src` (Tom Lane)

If a table has been modified by `ALTER TABLE ADD COLUMN`, attempts to copy its data verbatim to another table could produce corrupt results in certain corner cases. The problem can only manifest in this precise form in 8.4 and later, but we patched earlier versions as well in case there are other code paths that could trigger the same bug.

- Fix possible failures during hot standby startup (Simon Riggs)
- Start hot standby faster when initial snapshot is incomplete (Simon Riggs)
- Fix race condition during toast table access from stale syscache entries (Tom Lane)

  The typical symptom was transient errors like "missing chunk number 0 for toast value NNNNN in pg_toast_2619", where the cited toast table would always belong to a system catalog.
- Track dependencies of functions on items used in parameter default expressions (Tom Lane)

  Previously, a referenced object could be dropped without having dropped or modified the function, leading to misbehavior when the function was used. Note that merely installing this update will not fix the missing dependency entries; to do that, you'd need to `CREATE OR REPLACE` each such function afterwards. If you have functions whose defaults depend on non-built-in objects, doing so is recommended.
- Fix incorrect management of placeholder variables in nestloop joins (Tom Lane)

  This bug is known to lead to "variable not found in subplan target list" planner errors, and could possibly result in wrong query output when outer joins are involved.
- Fix window functions that sort by expressions involving aggregates (Tom Lane)

  Previously these could fail with "could not find pathkey item to sort" planner errors.
- Fix "MergeAppend child's targetlist doesn't match MergeAppend" planner errors (Tom Lane)
- Fix index matching for operators with both collatable and noncollatable inputs (Tom Lane)

  In 9.1.0, an indexable operator that has a non-collatable left-hand input type and a collatable right-hand input type would not be recognized as matching the left-hand column's index. An example is the `hstore ? text` operator.
- Allow inlining of set-returning SQL functions with multiple OUT parameters (Tom Lane)
- Don't trust deferred-unique indexes for join removal (Tom Lane and Marti Raudsepp)

  A deferred uniqueness constraint might not hold intra-transaction, so assuming that it does could give incorrect query results.
- Make `DatumGetInetP()` unpack inet datums that have a 1-byte header, and add a new macro, `DatumGetInetPP()`, that does not (Heikki Linnakangas)

  This change affects no core code, but might prevent crashes in add-on code that expects `DatumGetInetP()` to produce an unpacked datum as per usual convention.
- Improve locale support in `money` type's input and output (Tom Lane)

  Aside from not supporting all standard `lc_monetary` formatting options, the input and output functions were inconsistent, meaning there were locales in which dumped `money` values could not be re-read.
- Don't let `transform_null_equals` affect `CASE foo WHEN NULL ...` constructs (Heikki Linnakangas)

  `transform_null_equals` is only supposed to affect `foo = NULL` expressions written directly by the user, not equality checks generated internally by this form of `CASE`.
- Change foreign-key trigger creation order to better support self-referential foreign keys (Tom Lane)

For a cascading foreign key that references its own table, a row update will fire both the `ON UPDATE` trigger and the `CHECK` trigger as one event. The `ON UPDATE` trigger must execute first, else the `CHECK` will check a non-final state of the row and possibly throw an inappropriate error. However, the firing order of these triggers is determined by their names, which generally sort in creation order since the triggers have auto-generated names following the convention "RI_ConstraintTrigger_NNNN". A proper fix would require modifying that convention, which we will do in 9.2, but it seems risky to change it in existing releases. So this patch just changes the creation order of the triggers. Users encountering this type of error should drop and re-create the foreign key constraint to get its triggers into the right order.

- Fix `IF EXISTS` to work correctly in `DROP OPERATOR FAMILY` (Robert Haas)
- Disallow dropping of an extension from within its own script (Tom Lane)

  This prevents odd behavior in case of incorrect management of extension dependencies.
- Don't mark auto-generated types as extension members (Robert Haas)

  Relation rowtypes and automatically-generated array types do not need to have their own extension membership entries in `pg_depend`, and creating such entries complicates matters for extension upgrades.
- Cope with invalid pre-existing `search_path` settings during `CREATE EXTENSION` (Tom Lane)
- Avoid floating-point underflow while tracking buffer allocation rate (Greg Matthews)

  While harmless in itself, on certain platforms this would result in annoying kernel log messages.
- Prevent autovacuum transactions from running in serializable mode (Tom Lane)

  Autovacuum formerly used the cluster-wide default transaction isolation level, but there is no need for it to use anything higher than READ COMMITTED, and using SERIALIZABLE could result in unnecessary delays for other processes.
- Ensure walsender processes respond promptly to SIGTERM (Magnus Hagander)
- Exclude `postmaster.opts` from base backups (Magnus Hagander)
- Preserve configuration file name and line number values when starting child processes under Windows (Tom Lane)

  Formerly, these would not be displayed correctly in the `pg_settings` view.
- Fix incorrect field alignment in ecpg's SQLDA area (Zoltan Boszormenyi)
- Preserve blank lines within commands in psql's command history (Robert Haas)

  The former behavior could cause problems if an empty line was removed from within a string literal, for example.
- Avoid platform-specific infinite loop in pg_dump (Steve Singer)
- Fix compression of plain-text output format in pg_dump (Adrian Klaver and Tom Lane)

  pg_dump has historically understood `-Z` with no `-F` switch to mean that it should emit a gzip-compressed version of its plain text output. Restore that behavior.
- Fix pg_dump to dump user-defined casts between auto-generated types, such as table rowtypes (Tom Lane)
- Fix missed quoting of foreign server names in pg_dump (Tom Lane)
- Assorted fixes for pg_upgrade (Bruce Momjian)

  Handle exclusion constraints correctly, avoid failures on Windows, don't complain about mismatched toast table names in 8.4 databases.

- In PL/pgSQL, allow foreign tables to define row types (Alexander Soudakov)
- Fix up conversions of PL/Perl functions' results (Alex Hunsaker and Tom Lane)

  Restore the pre-9.1 behavior that PL/Perl functions returning `void` ignore the result value of their last Perl statement; 9.1.0 would throw an error if that statement returned a reference. Also, make sure it works to return a string value for a composite type, so long as the string meets the type's input format. In addition, throw errors for attempts to return Perl arrays or hashes when the function's declared result type is not an array or composite type, respectively. (Pre-9.1 versions rather uselessly returned strings like `ARRAY(0x221a9a0)` or `HASH(0x221aa90)` in such cases.)
- Ensure PL/Perl strings are always correctly UTF8-encoded (Amit Khandekar and Alex Hunsaker)
- Use the preferred version of xsubpp to build PL/Perl, not necessarily the operating system's main copy (David Wheeler and Alex Hunsaker)
- Correctly propagate SQLSTATE in PL/Python exceptions (Mika Eloranta and Jan Urbanski)
- Do not install PL/Python extension files for Python major versions other than the one built against (Peter Eisentraut)
- Change all the `contrib` extension script files to report a useful error message if they are fed to psql (Andrew Dunstan and Tom Lane)

  This should help teach people about the new method of using `CREATE EXTENSION` to load these files. In most cases, sourcing the scripts directly would fail anyway, but with harder-to-interpret messages.
- Fix incorrect coding in `contrib/dict_int` and `contrib/dict_xsyn` (Tom Lane)

  Some functions incorrectly assumed that memory returned by `palloc()` is guaranteed zeroed.
- Remove `contrib/sepgsql` tests from the regular regression test mechanism (Tom Lane)

  Since these tests require root privileges for setup, they're impractical to run automatically. Switch over to a manual approach instead, and provide a testing script to help with that.
- Fix assorted errors in `contrib/unaccent`'s configuration file parsing (Tom Lane)
- Honor query cancel interrupts promptly in `pgstatindex()` (Robert Haas)
- Fix incorrect quoting of log file name in Mac OS X start script (Sidar Lopez)
- Revert unintentional enabling of `WAL_DEBUG` (Robert Haas)

  Fortunately, as debugging tools go, this one is pretty cheap; but it's not intended to be enabled by default, so revert.
- Ensure VPATH builds properly install all server header files (Peter Eisentraut)
- Shorten file names reported in verbose error messages (Peter Eisentraut)

  Regular builds have always reported just the name of the C file containing the error message call, but VPATH builds formerly reported an absolute path name.
- Fix interpretation of Windows timezone names for Central America (Tom Lane)

  Map "Central America Standard Time" to `CST6`, not `CST6CDT`, because DST is generally not observed anywhere in Central America.
- Update time zone data files to tzdata release 2011n for DST law changes in Brazil, Cuba, Fiji, Palestine, Russia, and Samoa; also historical corrections for Alaska and British East Africa.

E.35. Release 9.1.1

Release Date: 2011-09-26

This release contains a small number of fixes from 9.1.0. For information about new features in the 9.1 major release, see Section E.36.

E.35.1. Migration to Version 9.1.1

A dump/restore is not required for those running 9.1.X.

E.35.2. Changes

- Make `pg_options_to_table` return NULL for an option with no value (Tom Lane)

  Previously such cases would result in a server crash.

- Fix memory leak at end of a GiST index scan (Tom Lane)

  Commands that perform many separate GiST index scans, such as verification of a new GiST-based exclusion constraint on a table already containing many rows, could transiently require large amounts of memory due to this leak.

- Fix explicit reference to `pg_temp` schema in `CREATE TEMPORARY TABLE` (Robert Haas)

  This used to be allowed, but failed in 9.1.0.

E.36. Release 9.1

Release Date: 2011-09-12

E.36.1. Overview

This release shows PostgreSQL moving beyond the traditional relational-database feature set with new, ground-breaking functionality that is unique to PostgreSQL. The streaming replication feature introduced in release 9.0 is significantly enhanced by adding a synchronous-replication option, streaming backups, and monitoring improvements. Major enhancements include:

- Allow synchronous replication
- Add support for foreign tables
- Add per-column collation support
- Add extensions which simplify packaging of additions to PostgreSQL
- Add a true serializable isolation level

- Support unlogged tables using the UNLOGGED option in CREATE TABLE
- Allow data-modification commands (INSERT/UPDATE/DELETE) in WITH clauses
- Add nearest-neighbor (order-by-operator) searching to GiST indexes
- Add a SECURITY LABEL command and support for SELinux permissions control
- Update the PL/Python server-side language

The above items are explained in more detail in the sections below.

E.36.2. Migration to Version 9.1

A dump/restore using pg_dump, or use of pg_upgrade, is required for those wishing to migrate data from any previous release.

Version 9.1 contains a number of changes that may affect compatibility with previous releases. Observe the following incompatibilities:

E.36.2.1. Strings

- Change the default value of standard_conforming_strings to on (Robert Haas)

  By default, backslashes are now ordinary characters in string literals, not escape characters. This change removes a long-standing incompatibility with the SQL standard. escape_string_warning has produced warnings about this usage for years. E″ strings are the proper way to embed backslash escapes in strings and are unaffected by this change.

> **Warning**
>
> This change can break applications that are not expecting it and do their own string escaping according to the old rules. The consequences could be as severe as introducing SQL-injection security holes. Be sure to test applications that are exposed to untrusted input, to ensure that they correctly handle single quotes and backslashes in text strings.

E.36.2.2. Casting

- Disallow function-style and attribute-style data type casts for composite types (Tom Lane)

  For example, disallow *composite_value*.text and text(*composite_value*). Unintentional uses of this syntax have frequently resulted in bug reports; although it was not a bug, it seems better to go back to rejecting such expressions. The CAST and :: syntaxes are still available for use when a cast of an entire composite value is actually intended.

- Tighten casting checks for domains based on arrays (Tom Lane)

  When a domain is based on an array type, it is allowed to "look through" the domain type to access the array elements, including subscripting the domain value to fetch or assign an element. Assignment to an element of such a domain value, for instance via UPDATE ... SET domaincol[5] = ..., will now result in rechecking the domain type's constraints, whereas before the checks were skipped.

E.36.2.3. Arrays

- Change `string_to_array()` to return an empty array for a zero-length string (Pavel Stehule)

  Previously this returned a null value.

- Change `string_to_array()` so a `NULL` separator splits the string into characters (Pavel Stehule)

  Previously this returned a null value.

E.36.2.4. Object Modification

- Fix improper checks for before/after triggers (Tom Lane)

  Triggers can now be fired in three cases: `BEFORE`, `AFTER`, or `INSTEAD OF` some action. Trigger function authors should verify that their logic behaves sanely in all three cases.

- Require superuser or `CREATEROLE` permissions in order to set comments on roles (Tom Lane)

E.36.2.5. Server Settings

- Change `pg_last_xlog_receive_location()` so it never moves backwards (Fujii Masao)

  Previously, the value of `pg_last_xlog_receive_location()` could move backward when streaming replication is restarted.

- Have logging of replication connections honor `log_connections` (Magnus Hagander)

  Previously, replication connections were always logged.

E.36.2.6. PL/pgSQL Server-Side Language

- Change PL/pgSQL's `RAISE` command without parameters to be catchable by the attached exception block (Piyush Newe)

  Previously `RAISE` in a code block was always scoped to an attached exception block, so it was uncatchable at the same scope.

- Adjust PL/pgSQL's error line numbering code to be consistent with other PLs (Pavel Stehule)

  Previously, PL/pgSQL would ignore (not count) an empty line at the start of the function body. Since this was inconsistent with all other languages, the special case was removed.

- Make PL/pgSQL complain about conflicting IN and OUT parameter names (Tom Lane)

  Formerly, the collision was not detected, and the name would just silently refer to only the OUT parameter.

- Type modifiers of PL/pgSQL variables are now visible to the SQL parser (Tom Lane)

  A type modifier (such as a varchar length limit) attached to a PL/pgSQL variable was formerly enforced during assignments, but was ignored for all other purposes. Such variables will now behave more like table columns declared with the same modifier. This is not expected to make any visible difference in most cases, but it could result in subtle changes for some SQL commands issued by PL/pgSQL functions.

E.36.2.7. Contrib

- All contrib modules are now installed with `CREATE EXTENSION` rather than by manually invoking their SQL scripts (Dimitri Fontaine, Tom Lane)

  To update an existing database containing the 9.0 version of a contrib module, use `CREATE EXTENSION ... FROM unpackaged` to wrap the existing contrib module's objects into an extension. When updating from a pre-9.0 version, drop the contrib module's objects using its old uninstall script, then use `CREATE EXTENSION`.

E.36.2.8. Other Incompatibilities

- Make `pg_stat_reset()` reset all database-level statistics (Tomas Vondra)

  Some `pg_stat_database` counters were not being reset.
- Fix some `information_schema.triggers` column names to match the new SQL-standard names (Dean Rasheed)
- Treat ECPG cursor names as case-insensitive (Zoltan Boszormenyi)

E.36.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 9.1 and the previous major release.

E.36.3.1. Server

E.36.3.1.1. Performance

- Support unlogged tables using the `UNLOGGED` option in `CREATE TABLE` (Robert Haas)

  Such tables provide better update performance than regular tables, but are not crash-safe: their contents are automatically cleared in case of a server crash. Their contents do not propagate to replication slaves, either.
- Allow `FULL OUTER JOIN` to be implemented as a hash join, and allow either side of a `LEFT OUTER JOIN` or `RIGHT OUTER JOIN` to be hashed (Tom Lane)

  Previously `FULL OUTER JOIN` could only be implemented as a merge join, and `LEFT OUTER JOIN` and `RIGHT OUTER JOIN` could hash only the nullable side of the join. These changes provide additional query optimization possibilities.
- Merge duplicate fsync requests (Robert Haas, Greg Smith)

  This greatly improves performance under heavy write loads.
- Improve performance of `commit_siblings` (Greg Smith)

  This allows the use of `commit_siblings` with less overhead.
- Reduce the memory requirement for large ispell dictionaries (Pavel Stehule, Tom Lane)
- Avoid leaving data files open after "blind writes" (Alvaro Herrera)

This fixes scenarios in which backends might hold files open long after they were deleted, preventing the kernel from reclaiming disk space.

E.36.3.1.2. Optimizer

- Allow inheritance table scans to return meaningfully-sorted results (Greg Stark, Hans-Jurgen Schonig, Robert Haas, Tom Lane)

  This allows better optimization of queries that use `ORDER BY`, `LIMIT`, or `MIN`/`MAX` with inherited tables.
- Improve GIN index scan cost estimation (Teodor Sigaev)
- Improve cost estimation for aggregates and window functions (Tom Lane)

E.36.3.1.3. Authentication

- Support host names and host suffixes (e.g. `.example.com`) in `pg_hba.conf` (Peter Eisentraut)

  Previously only host IP addresses and CIDR values were supported.
- Support the key word `all` in the host column of `pg_hba.conf` (Peter Eisentraut)

  Previously people used `0.0.0.0/0` or `::/0` for this.
- Reject `local` lines in `pg_hba.conf` on platforms that don't support Unix-socket connections (Magnus Hagander)

  Formerly, such lines were silently ignored, which could be surprising. This makes the behavior more like other unsupported cases.
- Allow GSSAPI to be used to authenticate to servers via SSPI (Christian Ullrich)

  Specifically this allows Unix-based GSSAPI clients to do SSPI authentication with Windows servers.
- `ident` authentication over local sockets is now known as `peer` (Magnus Hagander)

  The old term is still accepted for backward compatibility, but since the two methods are fundamentally different, it seemed better to adopt different names for them.
- Rewrite peer authentication to avoid use of credential control messages (Tom Lane)

  This change makes the peer authentication code simpler and better-performing. However, it requires the platform to provide the `getpeereid` function or an equivalent socket operation. So far as is known, the only platform for which peer authentication worked before and now will not is pre-5.0 NetBSD.

E.36.3.1.4. Monitoring

- Add details to the logging of restartpoints and checkpoints, which is controlled by `log_checkpoints` (Fujii Masao, Greg Smith)

  New details include WAL file and sync activity.
- Add `log_file_mode` which controls the permissions on log files created by the logging collector (Martin Pihlak)
- Reduce the default maximum line length for syslog logging to 900 bytes plus prefixes (Noah Misch)

This avoids truncation of long log lines on syslog implementations that have a 1KB length limit, rather than the more common 2KB.

E.36.3.1.5. Statistical Views

- Add `client_hostname` column to `pg_stat_activity` (Peter Eisentraut)

  Previously only the client address was reported.

- Add `pg_stat_xact_*` statistics functions and views (Joel Jacobson)

  These are like the database-wide statistics counter views, but reflect counts for only the current transaction.

- Add time of last reset in database-level and background writer statistics views (Tomas Vondra)

- Add columns showing the number of vacuum and analyze operations in `pg_stat_*_tables` views (Magnus Hagander)

- Add `buffers_backend_fsync` column to `pg_stat_bgwriter` (Greg Smith)

  This new column counts the number of times a backend fsyncs a buffer.

E.36.3.1.6. Server Settings

- Provide auto-tuning of `wal_buffers` (Greg Smith)

  By default, the value of `wal_buffers` is now chosen automatically based on the value of `shared_buffers`.

- Increase the maximum values for `deadlock_timeout`, `log_min_duration_statement`, and `log_autovacuum_min_duration` (Peter Eisentraut)

  The maximum value for each of these parameters was previously only about 35 minutes. Much larger values are now allowed.

E.36.3.2. Replication and Recovery

E.36.3.2.1. Streaming Replication and Continuous Archiving

- Allow synchronous replication (Simon Riggs, Fujii Masao)

  This allows the primary server to wait for a standby to write a transaction's information to disk before acknowledging the commit. One standby at a time can take the role of the synchronous standby, as controlled by the `synchronous_standby_names` setting. Synchronous replication can be enabled or disabled on a per-transaction basis using the `synchronous_commit` setting.

- Add protocol support for sending file system backups to standby servers using the streaming replication network connection (Magnus Hagander, Heikki Linnakangas)

  This avoids the requirement of manually transferring a file system backup when setting up a standby server.

- Add `replication_timeout` setting (Fujii Masao, Heikki Linnakangas)

Replication connections that are idle for more than the `replication_timeout` interval will be terminated automatically. Formerly, a failed connection was typically not detected until the TCP timeout elapsed, which is inconveniently long in many situations.

- Add command-line tool pg_basebackup for creating a new standby server or database backup (Magnus Hagander)
- Add a replication permission for roles (Magnus Hagander)

  This is a read-only permission used for streaming replication. It allows a non-superuser role to be used for replication connections. Previously only superusers could initiate replication connections; superusers still have this permission by default.

E.36.3.2.2. Replication Monitoring

- Add system view `pg_stat_replication` which displays activity of WAL sender processes (Itagaki Takahiro, Simon Riggs)

  This reports the status of all connected standby servers.
- Add monitoring function `pg_last_xact_replay_timestamp()` (Fujii Masao)

  This returns the time at which the primary generated the most recent commit or abort record applied on the standby.

E.36.3.2.3. Hot Standby

- Add configuration parameter `hot_standby_feedback` to enable standbys to postpone cleanup of old row versions on the primary (Simon Riggs)

  This helps avoid canceling long-running queries on the standby.
- Add the `pg_stat_database_conflicts` system view to show queries that have been canceled and the reason (Magnus Hagander)

  Cancellations can occur because of dropped tablespaces, lock timeouts, old snapshots, pinned buffers, and deadlocks.
- Add a `conflicts` count to `pg_stat_database` (Magnus Hagander)

  This is the number of conflicts that occurred in the database.
- Increase the maximum values for `max_standby_archive_delay` and `max_standby_streaming_delay`

  The maximum value for each of these parameters was previously only about 35 minutes. Much larger values are now allowed.
- Add `ERRCODE_T_R_DATABASE_DROPPED` error code to report recovery conflicts due to dropped databases (Tatsuo Ishii)

  This is useful for connection pooling software.

E.36.3.2.4. Recovery Control

- Add functions to control streaming replication replay (Simon Riggs)

The new functions are `pg_xlog_replay_pause()`, `pg_xlog_replay_resume()`, and the status function `pg_is_xlog_replay_paused()`.

- Add `recovery.conf` setting `pause_at_recovery_target` to pause recovery at target (Simon Riggs)

  This allows a recovery server to be queried to check whether the recovery point is the one desired.

- Add the ability to create named restore points using `pg_create_restore_point()` (Jaime Casanova)

  These named restore points can be specified as recovery targets using the new `recovery.conf` setting `recovery_target_name`.

- Allow standby recovery to switch to a new timeline automatically (Heikki Linnakangas)

  Now standby servers scan the archive directory for new timelines periodically.

- Add `restart_after_crash` setting which disables automatic server restart after a backend crash (Robert Haas)

  This allows external cluster management software to control whether the database server restarts or not.

- Allow `recovery.conf` to use the same quoting behavior as `postgresql.conf` (Dimitri Fontaine)

  Previously all values had to be quoted.

E.36.3.3. Queries

- Add a true serializable isolation level (Kevin Grittner, Dan Ports)

  Previously, asking for serializable isolation guaranteed only that a single MVCC snapshot would be used for the entire transaction, which allowed certain documented anomalies. The old snapshot isolation behavior is still available by requesting the `REPEATABLE READ` isolation level.

- Allow data-modification commands (`INSERT`/`UPDATE`/`DELETE`) in `WITH` clauses (Marko Tiikkaja, Hitoshi Harada)

  These commands can use `RETURNING` to pass data up to the containing query.

- Allow `WITH` clauses to be attached to `INSERT`, `UPDATE`, `DELETE` statements (Marko Tiikkaja, Hitoshi Harada)

- Allow non-`GROUP BY` columns in the query target list when the primary key is specified in the `GROUP BY` clause (Peter Eisentraut)

  The SQL standard allows this behavior, and because of the primary key, the result is unambiguous.

- Allow use of the key word `DISTINCT` in `UNION`/`INTERSECT`/`EXCEPT` clauses (Tom Lane)

  `DISTINCT` is the default behavior so use of this key word is redundant, but the SQL standard allows it.

- Fix ordinary queries with rules to use the same snapshot behavior as `EXPLAIN ANALYZE` (Marko Tiikkaja)

  Previously `EXPLAIN ANALYZE` used slightly different snapshot timing for queries involving rules. The `EXPLAIN ANALYZE` behavior was judged to be more logical.

E.36.3.3.1. Strings

- Add per-column collation support (Peter Eisentraut, Tom Lane)

  Previously collation (the sort ordering of text strings) could only be chosen at database creation. Collation can now be set per column, domain, index, or expression, via the SQL-standard `COLLATE` clause.

E.36.3.4. Object Manipulation

- Add extensions which simplify packaging of additions to PostgreSQL (Dimitri Fontaine, Tom Lane)

  Extensions are controlled by the new `CREATE`/`ALTER`/`DROP EXTENSION` commands. This replaces ad-hoc methods of grouping objects that are added to a PostgreSQL installation.

- Add support for foreign tables (Shigeru Hanada, Robert Haas, Jan Urbanski, Heikki Linnakangas)

  This allows data stored outside the database to be used like native PostgreSQL-stored data. Foreign tables are currently read-only, however.

- Allow new values to be added to an existing enum type via `ALTER TYPE` (Andrew Dunstan)

- Add `ALTER TYPE ... ADD/DROP/ALTER/RENAME ATTRIBUTE` (Peter Eisentraut)

  This allows modification of composite types.

E.36.3.4.1. *ALTER* Object

- Add `RESTRICT`/`CASCADE` to `ALTER TYPE` operations on typed tables (Peter Eisentraut)

  This controls `ADD`/`DROP`/`ALTER`/`RENAME ATTRIBUTE` cascading behavior.

- Support `ALTER TABLE` *`name`* `{OF | NOT OF}` *`type`* (Noah Misch)

  This syntax allows a standalone table to be made into a typed table, or a typed table to be made standalone.

- Add support for more object types in `ALTER ... SET SCHEMA` commands (Dimitri Fontaine)

  This command is now supported for conversions, operators, operator classes, operator families, text search configurations, text search dictionaries, text search parsers, and text search templates.

E.36.3.4.2. *CREATE/ALTER TABLE*

- Add `ALTER TABLE ... ADD UNIQUE/PRIMARY KEY USING INDEX` (Gurjeet Singh)

  This allows a primary key or unique constraint to be defined using an existing unique index, including a concurrently created unique index.

- Allow `ALTER TABLE` to add foreign keys without validation (Simon Riggs)

  The new option is called `NOT VALID`. The constraint's state can later be modified to `VALIDATED` and validation checks performed. Together these allow you to add a foreign key with minimal impact on read and write operations.

- Allow `ALTER TABLE ... SET DATA TYPE` to avoid table rewrites in appropriate cases (Noah Misch, Robert Haas)

  For example, converting a `varchar` column to `text` no longer requires a rewrite of the table. However, increasing the length constraint on a `varchar` column still requires a table rewrite.

- Add `CREATE TABLE IF NOT EXISTS` syntax (Robert Haas)

  This allows table creation without causing an error if the table already exists.

- Fix possible "tuple concurrently updated" error when two backends attempt to add an inheritance child to the same table at the same time (Robert Haas)

  `ALTER TABLE` now takes a stronger lock on the parent table, so that the sessions cannot try to update it simultaneously.

E.36.3.4.3. Object Permissions

- Add a `SECURITY LABEL` command (KaiGai Kohei)

  This allows security labels to be assigned to objects.

E.36.3.5. Utility Operations

- Add transaction-level advisory locks (Marko Tiikkaja)

  These are similar to the existing session-level advisory locks, but such locks are automatically released at transaction end.

- Make `TRUNCATE ... RESTART IDENTITY` restart sequences transactionally (Steve Singer)

  Previously the counter could have been left out of sync if a backend crashed between the on-commit truncation activity and commit completion.

E.36.3.5.1. `COPY`

- Add `ENCODING` option to `COPY TO/FROM` (Hitoshi Harada, Itagaki Takahiro)

  This allows the encoding of the `COPY` file to be specified separately from client encoding.

- Add bidirectional `COPY` protocol support (Fujii Masao)

  This is currently only used by streaming replication.

E.36.3.5.2. `EXPLAIN`

- Make `EXPLAIN VERBOSE` show the function call expression in a `FunctionScan` node (Tom Lane)

E.36.3.5.3. `VACUUM`

- Add additional details to the output of `VACUUM FULL VERBOSE` and `CLUSTER VERBOSE` (Itagaki Takahiro)

New information includes the live and dead tuple count and whether `CLUSTER` is using an index to rebuild.

- Prevent autovacuum from waiting if it cannot acquire a table lock (Robert Haas)

  It will try to vacuum that table later.

E.36.3.5.4. `CLUSTER`

- Allow `CLUSTER` to sort the table rather than scanning the index when it seems likely to be cheaper (Leonardo Francalanci)

E.36.3.5.5. Indexes

- Add nearest-neighbor (order-by-operator) searching to GiST indexes (Teodor Sigaev, Tom Lane)

  This allows GiST indexes to quickly return the *N* closest values in a query with `LIMIT`. For example

  ```
  SELECT * FROM places ORDER BY location <-> point '(101,456)' LIMIT 10;
  ```

  finds the ten places closest to a given target point.
- Allow GIN indexes to index null and empty values (Tom Lane)

  This allows full GIN index scans, and fixes various corner cases in which GIN scans would fail.
- Allow GIN indexes to better recognize duplicate search entries (Tom Lane)

  This reduces the cost of index scans, especially in cases where it avoids unnecessary full index scans.
- Fix GiST indexes to be fully crash-safe (Heikki Linnakangas)

  Previously there were rare cases where a `REINDEX` would be required (you would be informed).

E.36.3.6. Data Types

- Allow `numeric` to use a more compact, two-byte header in common cases (Robert Haas)

  Previously all `numeric` values had four-byte headers; this change saves on disk storage.
- Add support for dividing `money` by `money` (Andy Balholm)
- Allow binary I/O on type `void` (Radoslaw Smogura)
- Improve hypotenuse calculations for geometric operators (Paul Matthews)

  This avoids unnecessary overflows, and may also be more accurate.
- Support hashing array values (Tom Lane)

  This provides additional query optimization possibilities.
- Don't treat a composite type as sortable unless all its column types are sortable (Tom Lane)

  This avoids possible "could not identify a comparison function" failures at runtime, if it is possible to implement the query without sorting. Also, `ANALYZE` won't try to use inappropriate statistics-gathering methods for columns of such composite types.

E.36.3.6.1. Casting

- Add support for casting between `money` and `numeric` (Andy Balholm)
- Add support for casting from `int4` and `int8` to `money` (Joey Adams)
- Allow casting a table's row type to the table's supertype if it's a typed table (Peter Eisentraut)

  This is analogous to the existing facility that allows casting a row type to a supertable's row type.

E.36.3.6.2. XML

- Add XML function `XMLEXISTS` and `xpath_exists()` functions (Mike Fowler)

  These are used for XPath matching.
- Add XML functions `xml_is_well_formed()`, `xml_is_well_formed_document()`, `xml_is_well_formed_content()` (Mike Fowler)

  These check whether the input is properly-formed XML. They provide functionality that was previously available only in the deprecated `contrib/xml2` module.

E.36.3.7. Functions

- Add SQL function `format(text, ...)`, which behaves analogously to C's `printf()` (Pavel Stehule, Robert Haas)

  It currently supports formats for strings, SQL literals, and SQL identifiers.
- Add string functions `concat()`, `concat_ws()`, `left()`, `right()`, and `reverse()` (Pavel Stehule)

  These improve compatibility with other database products.
- Add function `pg_read_binary_file()` to read binary files (Dimitri Fontaine, Itagaki Takahiro)
- Add a single-parameter version of function `pg_read_file()` to read an entire file (Dimitri Fontaine, Itagaki Takahiro)
- Add three-parameter forms of `array_to_string()` and `string_to_array()` for null value processing control (Pavel Stehule)

E.36.3.7.1. Object Information Functions

- Add the `pg_describe_object()` function (Alvaro Herrera)

  This function is used to obtain a human-readable string describing an object, based on the `pg_class` OID, object OID, and sub-object ID. It can be used to help interpret the contents of `pg_depend`.
- Update comments for built-in operators and their underlying functions (Tom Lane)

  Functions that are meant to be used via an associated operator are now commented as such.
- Add variable `quote_all_identifiers` to force the quoting of all identifiers in `EXPLAIN` and in system catalog functions like `pg_get_viewdef()` (Robert Haas)

  This makes exporting schemas to tools and other databases with different quoting rules easier.

- Add columns to the `information_schema.sequences` system view (Peter Eisentraut)

  Previously, though the view existed, the columns about the sequence parameters were unimplemented.

- Allow `public` as a pseudo-role name in `has_table_privilege()` and related functions (Alvaro Herrera)

  This allows checking for public permissions.

E.36.3.7.2. Function and Trigger Creation

- Support `INSTEAD OF` triggers on views (Dean Rasheed)

  This feature can be used to implement fully updatable views.

E.36.3.8. Server-Side Languages

E.36.3.8.1. PL/pgSQL Server-Side Language

- Add `FOREACH IN ARRAY` to PL/pgSQL (Pavel Stehule)

  This is more efficient and readable than previous methods of iterating through the elements of an array value.

- Allow `RAISE` without parameters to be caught in the same places that could catch a `RAISE ERROR` from the same location (Piyush Newe)

  The previous coding threw the error from the block containing the active exception handler. The new behavior is more consistent with other DBMS products.

E.36.3.8.2. PL/Perl Server-Side Language

- Allow generic record arguments to PL/Perl functions (Andrew Dunstan)

  PL/Perl functions can now be declared to accept type `record`. The behavior is the same as for any named composite type.

- Convert PL/Perl array arguments to Perl arrays (Alexey Klyukin, Alex Hunsaker)

  String representations are still available.

- Convert PL/Perl composite-type arguments to Perl hashes (Alexey Klyukin, Alex Hunsaker)

  String representations are still available.

E.36.3.8.3. PL/Python Server-Side Language

- Add table function support for PL/Python (Jan Urbanski)

  PL/Python can now return multiple `OUT` parameters and record sets.

- Add a validator to PL/Python (Jan Urbanski)

  This allows PL/Python functions to be syntax-checked at function creation time.

- Allow exceptions for SQL queries in PL/Python (Jan Urbanski)

  This allows access to SQL-generated exception error codes from PL/Python exception blocks.
- Add explicit subtransactions to PL/Python (Jan Urbanski)
- Add PL/Python functions for quoting strings (Jan Urbanski)

  These functions are `plpy.quote_ident`, `plpy.quote_literal`, and `plpy.quote_nullable`.
- Add traceback information to PL/Python errors (Jan Urbanski)
- Report PL/Python errors from iterators with `PLy_elog` (Jan Urbanski)
- Fix exception handling with Python 3 (Jan Urbanski)

  Exception classes were previously not available in `plpy` under Python 3.

E.36.3.9. Client Applications

- Mark createlang and droplang as deprecated now that they just invoke extension commands (Tom Lane)

E.36.3.9.1. psql

- Add psql command `\conninfo` to show current connection information (David Christensen)
- Add psql command `\sf` to show a function's definition (Pavel Stehule)
- Add psql command `\dL` to list languages (Fernando Ike)
- Add the `S` ("system") option to psql's `\dn` (list schemas) command (Tom Lane)

  `\dn` without `S` now suppresses system schemas.
- Allow psql's `\e` and `\ef` commands to accept a line number to be used to position the cursor in the editor (Pavel Stehule)

  This is passed to the editor according to the `PSQL_EDITOR_LINENUMBER_ARG` environment variable.
- Have psql set the client encoding from the operating system locale by default (Heikki Linnakangas)

  This only happens if the `PGCLIENTENCODING` environment variable is not set.
- Make `\d` distinguish between unique indexes and unique constraints (Josh Kupershmidt)
- Make `\dt+` report `pg_table_size` instead of `pg_relation_size` when talking to 9.0 or later servers (Bernd Helmle)

  This is a more useful measure of table size, but note that it is not identical to what was previously reported in the same display.
- Additional tab completion support (Itagaki Takahiro, Pavel Stehule, Andrey Popp, Christoph Berg, David Fetter, Josh Kupershmidt)

E.36.3.9.2. pg_dump

- Add pg_dump and pg_dumpall option `--quote-all-identifiers` to force quoting of all identifiers (Robert Haas)

- Add `directory` format to pg_dump (Joachim Wieland, Heikki Linnakangas)

  This is internally similar to the `tar` pg_dump format.

E.36.3.9.3. pg_ctl

- Fix pg_ctl so it no longer incorrectly reports that the server is not running (Bruce Momjian)

  Previously this could happen if the server was running but pg_ctl could not authenticate.

- Improve pg_ctl start's "wait" (`-w`) option (Bruce Momjian, Tom Lane)

  The wait mode is now significantly more robust. It will not get confused by non-default postmaster port numbers, non-default Unix-domain socket locations, permission problems, or stale postmaster lock files.

- Add `promote` option to pg_ctl to switch a standby server to primary (Fujii Masao)

E.36.3.10. Development Tools

E.36.3.10.1. libpq

- Add a libpq connection option `client_encoding` which behaves like the `PGCLIENTENCODING` environment variable (Heikki Linnakangas)

  The value `auto` sets the client encoding based on the operating system locale.

- Add `PQlibVersion()` function which returns the libpq library version (Magnus Hagander)

  libpq already had `PQserverVersion()` which returns the server version.

- Allow libpq-using clients to check the user name of the server process when connecting via Unix-domain sockets, with the new `requirepeer` connection option (Peter Eisentraut)

  PostgreSQL already allowed servers to check the client user name when connecting via Unix-domain sockets.

- Add `PQping()` and `PQpingParams()` to libpq (Bruce Momjian, Tom Lane)

  These functions allow detection of the server's status without trying to open a new session.

E.36.3.10.2. ECPG

- Allow ECPG to accept dynamic cursor names even in `WHERE CURRENT OF` clauses (Zoltan Boszormenyi)

- Make ecpglib write `double` values with a precision of 15 digits, not 14 as formerly (Akira Kurosawa)

E.36.3.11. Build Options

- Use `+Olibmerrno` compile flag with HP-UX C compilers that accept it (Ibrar Ahmed)

This avoids possible misbehavior of math library calls on recent HP platforms.

E.36.3.11.1. Makefiles

- Improved parallel make support (Peter Eisentraut)

  This allows for faster compiles. Also, `make -k` now works more consistently.
- Require GNU make 3.80 or newer (Peter Eisentraut)

  This is necessary because of the parallel-make improvements.
- Add `make maintainer-check` target (Peter Eisentraut)

  This target performs various source code checks that are not appropriate for either the build or the regression tests. Currently: duplicate_oids, SGML syntax and tabs check, NLS syntax check.
- Support `make check` in `contrib` (Peter Eisentraut)

  Formerly only `make installcheck` worked, but now there is support for testing in a temporary installation. The top-level `make check-world` target now includes testing `contrib` this way.

E.36.3.11.2. Windows

- On Windows, allow pg_ctl to register the service as auto-start or start-on-demand (Quan Zongliang)
- Add support for collecting crash dumps on Windows (Craig Ringer, Magnus Hagander)

  minidumps can now be generated by non-debug Windows binaries and analyzed by standard debugging tools.
- Enable building with the MinGW64 compiler (Andrew Dunstan)

  This allows building 64-bit Windows binaries even on non-Windows platforms via cross-compiling.

E.36.3.12. Source Code

- Revise the API for GUC variable assign hooks (Tom Lane)

  The previous functions of assign hooks are now split between check hooks and assign hooks, where the former can fail but the latter shouldn't. This change will impact add-on modules that define custom GUC parameters.
- Add latches to the source code to support waiting for events (Heikki Linnakangas)
- Centralize data modification permissions-checking logic (KaiGai Kohei)
- Add missing `get_`*`object`*`_oid()` functions, for consistency (Robert Haas)
- Improve ability to use C++ compilers for compiling add-on modules by removing conflicting key words (Tom Lane)
- Add support for DragonFly BSD (Rumko)
- Expose `quote_literal_cstr()` for backend use (Robert Haas)
- Run regression tests in the default encoding (Peter Eisentraut)

  Regression tests were previously always run with `SQL_ASCII` encoding.
- Add src/tools/git_changelog to replace cvs2cl and pgcvslog (Robert Haas, Tom Lane)

- Add git-external-diff script to `src/tools` (Bruce Momjian)

  This is used to generate context diffs from git.

- Improve support for building with Clang (Peter Eisentraut)

E.36.3.12.1. Server Hooks

- Add source code hooks to check permissions (Robert Haas, Stephen Frost)
- Add post-object-creation function hooks for use by security frameworks (KaiGai Kohei)
- Add a client authentication hook (KaiGai Kohei)

E.36.3.13. Contrib

- Modify `contrib` modules and procedural languages to install via the new extension mechanism (Tom Lane, Dimitri Fontaine)
- Add `contrib/file_fdw` foreign-data wrapper (Shigeru Hanada)

  Foreign tables using this foreign data wrapper can read flat files in a manner very similar to `COPY`.

- Add nearest-neighbor search support to `contrib/pg_trgm` and `contrib/btree_gist` (Teodor Sigaev)
- Add `contrib/btree_gist` support for searching on not-equals (Jeff Davis)
- Fix `contrib/fuzzystrmatch`'s `levenshtein()` function to handle multibyte characters (Alexander Korotkov)
- Add `ssl_cipher()` and `ssl_version()` functions to `contrib/sslinfo` (Robert Haas)
- Fix `contrib/intarray` and `contrib/hstore` to give consistent results with indexed empty arrays (Tom Lane)

  Previously an empty-array query that used an index might return different results from one that used a sequential scan.

- Allow `contrib/intarray` to work properly on multidimensional arrays (Tom Lane)
- In `contrib/intarray`, avoid errors complaining about the presence of nulls in cases where no nulls are actually present (Tom Lane)
- In `contrib/intarray`, fix behavior of containment operators with respect to empty arrays (Tom Lane)

  Empty arrays are now correctly considered to be contained in any other array.

- Remove `contrib/xml2`'s arbitrary limit on the number of *`parameter`*`=`*`value`* pairs that can be handled by `xslt_process()` (Pavel Stehule)

  The previous limit was 10.

- In `contrib/pageinspect`, fix heap_page_item to return infomasks as 32-bit values (Alvaro Herrera)

  This avoids returning negative values, which was confusing. The underlying value is a 16-bit unsigned integer.

E.36.3.13.1. Security

- Add `contrib/sepgsql` to interface permission checks with SELinux (KaiGai Kohei)

  This uses the new `SECURITY LABEL` facility.
- Add contrib module `auth_delay` (KaiGai Kohei)

  This causes the server to pause before returning authentication failure; it is designed to make brute force password attacks more difficult.
- Add `dummy_seclabel` contrib module (KaiGai Kohei)

  This is used for permission regression testing.

E.36.3.13.2. Performance

- Add support for `LIKE` and `ILIKE` index searches to `contrib/pg_trgm` (Alexander Korotkov)
- Add `levenshtein_less_equal()` function to `contrib/fuzzystrmatch`, which is optimized for small distances (Alexander Korotkov)
- Improve performance of index lookups on `contrib/seg` columns (Alexander Korotkov)
- Improve performance of pg_upgrade for databases with many relations (Bruce Momjian)
- Add flag to `contrib/pgbench` to report per-statement latencies (Florian Pflug)

E.36.3.13.3. Fsync Testing

- Move `src/tools/test_fsync` to `contrib/pg_test_fsync` (Bruce Momjian, Tom Lane)
- Add `O_DIRECT` support to `contrib/pg_test_fsync` (Bruce Momjian)

  This matches the use of `O_DIRECT` by `wal_sync_method`.
- Add new tests to `contrib/pg_test_fsync` (Bruce Momjian)

E.36.3.14. Documentation

- Extensive ECPG documentation improvements (Satoshi Nagayasu)
- Extensive proofreading and documentation improvements (Thom Brown, Josh Kupershmidt, Susanne Ebrecht)
- Add documentation for `exit_on_error` (Robert Haas)

  This parameter causes sessions to exit on any error.
- Add documentation for `pg_options_to_table()` (Josh Berkus)

  This function shows table storage options in a readable form.
- Document that it is possible to access all composite type fields using `(compositeval).*` syntax (Peter Eisentraut)
- Document that `translate()` removes characters in `from` that don't have a corresponding `to` character (Josh Kupershmidt)

- Merge documentation for `CREATE CONSTRAINT TRIGGER` and `CREATE TRIGGER` (Alvaro Herrera)
- Centralize permission and upgrade documentation (Bruce Momjian)
- Add kernel tuning documentation for Solaris 10 (Josh Berkus)

  Previously only Solaris 9 kernel tuning was documented.
- Handle non-ASCII characters consistently in `HISTORY` file (Peter Eisentraut)

  While the `HISTORY` file is in English, we do have to deal with non-ASCII letters in contributor names. These are now transliterated so that they are reasonably legible without assumptions about character set.

E.37. Release 9.0.19

Release Date: 2015-02-05

This release contains a variety of fixes from 9.0.18. For information about new features in the 9.0 major release, see Section E.56.

E.37.1. Migration to Version 9.0.19

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.18, see Section E.38.

E.37.2. Changes

- Fix buffer overruns in `to_char()` (Bruce Momjian)

  When `to_char()` processes a numeric formatting template calling for a large number of digits, PostgreSQL would read past the end of a buffer. When processing a crafted timestamp formatting template, PostgreSQL would write past the end of a buffer. Either case could crash the server. We have not ruled out the possibility of attacks that lead to privilege escalation, though they seem unlikely. (CVE-2015-0241)
- Fix buffer overrun in replacement `*printf()` functions (Tom Lane)

  PostgreSQL includes a replacement implementation of `printf` and related functions. This code will overrun a stack buffer when formatting a floating point number (conversion specifiers `e`, `E`, `f`, `F`, `g` or `G`) with requested precision greater than about 500. This will crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. A database user can trigger such a buffer overrun through the `to_char()` SQL function. While that is the only affected core PostgreSQL functionality, extension modules that use printf-family functions may be at risk as well.

  This issue primarily affects PostgreSQL on Windows. PostgreSQL uses the system implementation of these functions where adequate, which it is on other modern platforms. (CVE-2015-0242)

- Fix buffer overruns in `contrib/pgcrypto` (Marko Tiikkaja, Noah Misch)

  Errors in memory size tracking within the `pgcrypto` module permitted stack buffer overruns and improper dependence on the contents of uninitialized memory. The buffer overrun cases can crash the server, and we have not ruled out the possibility of attacks that lead to privilege escalation. (CVE-2015-0243)

- Fix possible loss of frontend/backend protocol synchronization after an error (Heikki Linnakangas)

  If any error occurred while the server was in the middle of reading a protocol message from the client, it could lose synchronization and incorrectly try to interpret part of the message's data as a new protocol message. An attacker able to submit crafted binary data within a command parameter might succeed in injecting his own SQL commands this way. Statement timeout and query cancellation are the most likely sources of errors triggering this scenario. Particularly vulnerable are applications that use a timeout and also submit arbitrary user-crafted data as binary query parameters. Disabling statement timeout will reduce, but not eliminate, the risk of exploit. Our thanks to Emil Lenngren for reporting this issue. (CVE-2015-0244)

- Fix information leak via constraint-violation error messages (Stephen Frost)

  Some server error messages show the values of columns that violate a constraint, such as a unique constraint. If the user does not have `SELECT` privilege on all columns of the table, this could mean exposing values that the user should not be able to see. Adjust the code so that values are displayed only when they came from the SQL command or could be selected by the user. (CVE-2014-8161)

- Lock down regression testing's temporary installations on Windows (Noah Misch)

  Use SSPI authentication to allow connections only from the OS user who launched the test suite. This closes on Windows the same vulnerability previously closed on other platforms, namely that other users might be able to connect to the test postmaster. (CVE-2014-0067)

- Avoid possible data corruption if `ALTER DATABASE SET TABLESPACE` is used to move a database to a new tablespace and then shortly later move it back to its original tablespace (Tom Lane)

- Avoid corrupting tables when `ANALYZE` inside a transaction is rolled back (Andres Freund, Tom Lane, Michael Paquier)

  If the failing transaction had earlier removed the last index, rule, or trigger from the table, the table would be left in a corrupted state with the relevant `pg_class` flags not set though they should be.

- Fix use-of-already-freed-memory problem in EvalPlanQual processing (Tom Lane)

  In `READ COMMITTED` mode, queries that lock or update recently-updated rows could crash as a result of this bug.

- Fix planning of `SELECT FOR UPDATE` when using a partial index on a child table (Kyotaro Horiguchi)

  In `READ COMMITTED` mode, `SELECT FOR UPDATE` must also recheck the partial index's `WHERE` condition when rechecking a recently-updated row to see if it still satisfies the query's `WHERE` condition. This requirement was missed if the index belonged to an inheritance child table, so that it was possible to incorrectly return rows that no longer satisfy the query condition.

- Fix corner case wherein `SELECT FOR UPDATE` could return a row twice, and possibly miss returning other rows (Tom Lane)

  In `READ COMMITTED` mode, a `SELECT FOR UPDATE` that is scanning an inheritance tree could incorrectly return a row from a prior child table instead of the one it should return from a later child table.

- Reject duplicate column names in the referenced-columns list of a `FOREIGN KEY` declaration (David Rowley)

This restriction is per SQL standard. Previously we did not reject the case explicitly, but later on the code would fail with bizarre-looking errors.

- Fix bugs in raising a `numeric` value to a large integral power (Tom Lane)

  The previous code could get a wrong answer, or consume excessive amounts of time and memory before realizing that the answer must overflow.

- In `numeric_recv()`, truncate away any fractional digits that would be hidden according to the value's `dscale` field (Tom Lane)

  A `numeric` value's display scale (`dscale`) should never be less than the number of nonzero fractional digits; but apparently there's at least one broken client application that transmits binary `numeric` values in which that's true. This leads to strange behavior since the extra digits are taken into account by arithmetic operations even though they aren't printed. The least risky fix seems to be to truncate away such "hidden" digits on receipt, so that the value is indeed what it prints as.

- Reject out-of-range numeric timezone specifications (Tom Lane)

  Simple numeric timezone specifications exceeding +/- 168 hours (one week) would be accepted, but could then cause null-pointer dereference crashes in certain operations. There's no use-case for such large UTC offsets, so reject them.

- Fix bugs in `tsquery @> tsquery` operator (Heikki Linnakangas)

  Two different terms would be considered to match if they had the same CRC. Also, if the second operand had more terms than the first, it would be assumed not to be contained in the first; which is wrong since it might contain duplicate terms.

- Improve ispell dictionary's defenses against bad affix files (Tom Lane)

- Allow more than 64K phrases in a thesaurus dictionary (David Boutin)

  The previous coding could crash on an oversize dictionary, so this was deemed a back-patchable bug fix rather than a feature addition.

- Fix namespace handling in `xpath()` (Ali Akbar)

  Previously, the `xml` value resulting from an `xpath()` call would not have namespace declarations if the namespace declarations were attached to an ancestor element in the input `xml` value, rather than to the specific element being returned. Propagate the ancestral declaration so that the result is correct when considered in isolation.

- Fix planner problems with nested append relations, such as inherited tables within `UNION ALL` subqueries (Tom Lane)

- Fail cleanly when a GiST index tuple doesn't fit on a page, rather than going into infinite recursion (Andrew Gierth)

- Exempt tables that have per-table `cost_limit` and/or `cost_delay` settings from autovacuum's global cost balancing rules (Álvaro Herrera)

  The previous behavior resulted in basically ignoring these per-table settings, which was unintended. Now, a table having such settings will be vacuumed using those settings, independently of what is going on in other autovacuum workers. This may result in heavier total I/O load than before, so such settings should be re-examined for sanity.

- Avoid wholesale autovacuuming when autovacuum is nominally off (Tom Lane)

  Even when autovacuum is nominally off, we will still launch autovacuum worker processes to vacuum tables that are at risk of XID wraparound. However, such a worker process then proceeded to vacuum all tables in the target database, if they met the usual thresholds for autovacuuming. This

is at best pretty unexpected; at worst it delays response to the wraparound threat. Fix it so that if autovacuum is turned off, workers *only* do anti-wraparound vacuums and not any other work.

- Fix race condition between hot standby queries and replaying a full-page image (Heikki Linnakangas)

  This mistake could result in transient errors in queries being executed in hot standby.

- Fix several cases where recovery logic improperly ignored WAL records for `COMMIT/ABORT PREPARED` (Heikki Linnakangas)

  The most notable oversight was that `recovery_min_apply_delay` failed to delay application of a two-phase commit.

- Avoid creating unnecessary `.ready` marker files for timeline history files (Fujii Masao)

- Fix possible null pointer dereference when an empty prepared statement is used and the `log_statement` setting is `mod` or `ddl` (Fujii Masao)

- Change "pgstat wait timeout" warning message to be LOG level, and rephrase it to be more understandable (Tom Lane)

  This message was originally thought to be essentially a can't-happen case, but it occurs often enough on our slower buildfarm members to be a nuisance. Reduce it to LOG level, and expend a bit more effort on the wording: it now reads "using stale statistics instead of current ones because stats collector is not responding".

- Fix SPARC spinlock implementation to ensure correctness if the CPU is being run in a non-TSO coherency mode, as some non-Solaris kernels do (Andres Freund)

- Warn if OS X's `setlocale()` starts an unwanted extra thread inside the postmaster (Noah Misch)

- Fix processing of repeated `dbname` parameters in `PQconnectdbParams()` (Alex Shulgin)

  Unexpected behavior ensued if the first occurrence of `dbname` contained a connection string or URI to be expanded.

- Ensure that libpq reports a suitable error message on unexpected socket EOF (Marko Tiikkaja, Tom Lane)

  Depending on kernel behavior, libpq might return an empty error string rather than something useful when the server unexpectedly closed the socket.

- Clear any old error message during `PQreset()` (Heikki Linnakangas)

  If `PQreset()` is called repeatedly, and the connection cannot be re-established, error messages from the failed connection attempts kept accumulating in the `PGconn`'s error string.

- Properly handle out-of-memory conditions while parsing connection options in libpq (Alex Shulgin, Heikki Linnakangas)

- Fix array overrun in ecpg's version of `ParseDateTime()` (Michael Paquier)

- In initdb, give a clearer error message if a password file is specified but is empty (Mats Erik Andersson)

- Fix psql's `\s` command to work nicely with libedit, and add pager support (Stepan Rutz, Tom Lane)

  When using libedit rather than readline, `\s` printed the command history in a fairly unreadable encoded format, and on recent libedit versions might fail altogether. Fix that by printing the history ourselves rather than having the library do it. A pleasant side-effect is that the pager is used if appropriate.

  This patch also fixes a bug that caused newline encoding to be applied inconsistently when saving the command history with libedit. Multiline history entries written by older psql versions will be

read cleanly with this patch, but perhaps not vice versa, depending on the exact libedit versions involved.

- Improve consistency of parsing of psql's special variables (Tom Lane)

  Allow variant spellings of `on` and `off` (such as `1`/`0`) for `ECHO_HIDDEN` and `ON_ERROR_ROLLBACK`. Report a warning for unrecognized values for `COMP_KEYWORD_CASE`, `ECHO`, `ECHO_HIDDEN`, `HISTCONTROL`, `ON_ERROR_ROLLBACK`, and `VERBOSITY`. Recognize all values for all these variables case-insensitively; previously there was a mishmash of case-sensitive and case-insensitive behaviors.

- Fix psql's expanded-mode display to work consistently when using `border` = 3 and `linestyle` = `ascii` or `unicode` (Stephen Frost)

- Fix possible deadlock during parallel restore of a schema-only dump (Robert Haas, Tom Lane)

- Fix core dump in `pg_dump --binary-upgrade` on zero-column composite type (Rushabh Lathia)

- Fix block number checking in `contrib/pageinspect`'s `get_raw_page()` (Tom Lane)

  The incorrect checking logic could prevent access to some pages in non-main relation forks.

- Fix `contrib/pgcrypto`'s `pgp_sym_decrypt()` to not fail on messages whose length is 6 less than a power of 2 (Marko Tiikkaja)

- Handle unexpected query results, especially NULLs, safely in `contrib/tablefunc`'s `connectby()` (Michael Paquier)

  `connectby()` previously crashed if it encountered a NULL key value. It now prints that row but doesn't recurse further.

- Avoid a possible crash in `contrib/xml2`'s `xslt_process()` (Mark Simonetti)

  libxslt seems to have an undocumented dependency on the order in which resources are freed; reorder our calls to avoid a crash.

- Numerous cleanups of warnings from Coverity static code analyzer (Andres Freund, Tatsuo Ishii, Marko Kreen, Tom Lane, Michael Paquier)

  These changes are mostly cosmetic but in some cases fix corner-case bugs, for example a crash rather than a proper error report after an out-of-memory failure. None are believed to represent security issues.

- Detect incompatible OpenLDAP versions during build (Noah Misch)

  With OpenLDAP versions 2.4.24 through 2.4.31, inclusive, PostgreSQL backends can crash at exit. Raise a warning during configure based on the compile-time OpenLDAP version number, and test the crashing scenario in the `contrib/dblink` regression test.

- In non-MSVC Windows builds, ensure `libpq.dll` is installed with execute permissions (Noah Misch)

- Make pg_regress remove any temporary installation it created upon successful exit (Tom Lane)

  This results in a very substantial reduction in disk space usage during `make check-world`, since that sequence involves creation of numerous temporary installations.

- Support time zone abbreviations that change UTC offset from time to time (Tom Lane)

  Previously, PostgreSQL assumed that the UTC offset associated with a time zone abbreviation (such as `EST`) never changes in the usage of any particular locale. However this assumption fails in the real world, so introduce the ability for a zone abbreviation to represent a UTC offset that sometimes changes. Update the zone abbreviation definition files to make use of this feature in

timezone locales that have changed the UTC offset of their abbreviations since 1970 (according to the IANA timezone database). In such timezones, PostgreSQL will now associate the correct UTC offset with the abbreviation depending on the given date.

- Update time zone abbreviations lists (Tom Lane)

  Add CST (China Standard Time) to our lists. Remove references to ADT as "Arabia Daylight Time", an abbreviation that's been out of use since 2007; therefore, claiming there is a conflict with "Atlantic Daylight Time" doesn't seem especially helpful. Fix entirely incorrect GMT offsets for CKT (Cook Islands), FJT, and FJST (Fiji); we didn't even have them on the proper side of the date line.

- Update time zone data files to tzdata release 2015a.

  The IANA timezone database has adopted abbreviations of the form `AxST`/`AxDT` for all Australian time zones, reflecting what they believe to be current majority practice Down Under. These names do not conflict with usage elsewhere (other than ACST for Acre Summer Time, which has been in disuse since 1994). Accordingly, adopt these names into our "Default" timezone abbreviation set. The "Australia" abbreviation set now contains only CST, EAST, EST, SAST, SAT, and WST, all of which are thought to be mostly historical usage. Note that SAST has also been changed to be South Africa Standard Time in the "Default" abbreviation set.

  Also, add zone abbreviations SRET (Asia/Srednekolymsk) and XJT (Asia/Urumqi), and use WSST/WSDT for western Samoa. Also, there were DST law changes in Chile, Mexico, the Turks & Caicos Islands (America/Grand_Turk), and Fiji. There is a new zone Pacific/Bougainville for portions of Papua New Guinea. Also, numerous corrections for historical (pre-1970) time zone data.

E.38. Release 9.0.18

Release Date: 2014-07-24

This release contains a variety of fixes from 9.0.17. For information about new features in the 9.0 major release, see Section E.56.

E.38.1. Migration to Version 9.0.18

A dump/restore is not required for those running 9.0.X.

However, this release corrects an index corruption problem in some GiST indexes. See the first changelog entry below to find out whether your installation has been affected and what steps you should take if so.

Also, if you are upgrading from a version earlier than 9.0.15, see Section E.41.

E.38.2. Changes

- Correctly initialize padding bytes in `contrib/btree_gist` indexes on `bit` columns (Heikki Linnakangas)

This error could result in incorrect query results due to values that should compare equal not being seen as equal. Users with GiST indexes on `bit` or `bit varying` columns should `REINDEX` those indexes after installing this update.

- Protect against torn pages when deleting GIN list pages (Heikki Linnakangas)

  This fix prevents possible index corruption if a system crash occurs while the page update is being written to disk.

- Don't clear the right-link of a GiST index page while replaying updates from WAL (Heikki Linnakangas)

  This error could lead to transiently wrong answers from GiST index scans performed in Hot Standby.

- Fix possibly-incorrect cache invalidation during nested calls to `ReceiveSharedInvalidMessages` (Andres Freund)

- Don't assume a subquery's output is unique if there's a set-returning function in its targetlist (David Rowley)

  This oversight could lead to misoptimization of constructs like `WHERE x IN (SELECT y, generate_series(1,10) FROM t GROUP BY y)`.

- Fix failure to detoast fields in composite elements of structured types (Tom Lane)

  This corrects cases where TOAST pointers could be copied into other tables without being dereferenced. If the original data is later deleted, it would lead to errors like "missing chunk number 0 for toast value ..." when the now-dangling pointer is used.

- Fix "record type has not been registered" failures with whole-row references to the output of Append plan nodes (Tom Lane)

- Fix possible crash when invoking a user-defined function while rewinding a cursor (Tom Lane)

- Fix query-lifespan memory leak while evaluating the arguments for a function in `FROM` (Tom Lane)

- Fix session-lifespan memory leaks in regular-expression processing (Tom Lane, Arthur O'Dwyer, Greg Stark)

- Fix data encoding error in `hungarian.stop` (Tom Lane)

- Fix liveness checks for rows that were inserted in the current transaction and then deleted by a now-rolled-back subtransaction (Andres Freund)

  This could cause problems (at least spurious warnings, and at worst an infinite loop) if `CREATE INDEX` or `CLUSTER` were done later in the same transaction.

- Clear `pg_stat_activity.xact_start` during `PREPARE TRANSACTION` (Andres Freund)

  After the `PREPARE`, the originating session is no longer in a transaction, so it should not continue to display a transaction start time.

- Fix `REASSIGN OWNED` to not fail for text search objects (Álvaro Herrera)

- Block signals during postmaster startup (Tom Lane)

  This ensures that the postmaster will properly clean up after itself if, for example, it receives SIGINT while still starting up.

- Secure Unix-domain sockets of temporary postmasters started during `make check` (Noah Misch)

  Any local user able to access the socket file could connect as the server's bootstrap superuser, then proceed to execute arbitrary code as the operating-system user running the test, as we previously noted in CVE-2014-0067. This change defends against that risk by placing the server's socket in a temporary, mode 0700 subdirectory of `/tmp`. The hazard remains however on platforms where

Unix sockets are not supported, notably Windows, because then the temporary postmaster must accept local TCP connections.

A useful side effect of this change is to simplify `make check` testing in builds that override `DEFAULT_PGSOCKET_DIR`. Popular non-default values like `/var/run/postgresql` are often not writable by the build user, requiring workarounds that will no longer be necessary.

- Fix tablespace creation WAL replay to work on Windows (MauMau)
- Fix detection of socket creation failures on Windows (Bruce Momjian)
- On Windows, allow new sessions to absorb values of PGC_BACKEND parameters (such as log_connections) from the configuration file (Amit Kapila)

  Previously, if such a parameter were changed in the file post-startup, the change would have no effect.
- Properly quote executable path names on Windows (Nikhil Deshpande)

  This oversight could cause initdb and pg_upgrade to fail on Windows, if the installation path contained both spaces and `@` signs.
- Fix linking of libpython on OS X (Tom Lane)

  The method we previously used can fail with the Python library supplied by Xcode 5.0 and later.
- Avoid buffer bloat in libpq when the server consistently sends data faster than the client can absorb it (Shin-ichi Morita, Tom Lane)

  libpq could be coerced into enlarging its input buffer until it runs out of memory (which would be reported misleadingly as "lost synchronization with server"). Under ordinary circumstances it's quite far-fetched that data could be continuously transmitted more quickly than the `recv()` loop can absorb it, but this has been observed when the client is artificially slowed by scheduler constraints.
- Ensure that LDAP lookup attempts in libpq time out as intended (Laurenz Albe)
- Fix ecpg to do the right thing when an array of `char *` is the target for a FETCH statement returning more than one row, as well as some other array-handling fixes (Ashutosh Bapat)
- Fix pg_restore's processing of old-style large object comments (Tom Lane)

  A direct-to-database restore from an archive file generated by a pre-9.0 version of pg_dump would usually fail if the archive contained more than a few comments for large objects.
- In `contrib/pgcrypto` functions, ensure sensitive information is cleared from stack variables before returning (Marko Kreen)
- In `contrib/uuid-ossp`, cache the state of the OSSP UUID library across calls (Tom Lane)

  This improves the efficiency of UUID generation and reduces the amount of entropy drawn from `/dev/urandom`, on platforms that have that.
- Update time zone data files to tzdata release 2014e for DST law changes in Crimea, Egypt, and Morocco.

E.39. Release 9.0.17

Release Date: 2014-03-20

This release contains a variety of fixes from 9.0.16. For information about new features in the 9.0 major release, see Section E.56.

E.39.1. Migration to Version 9.0.17

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.15, see Section E.41.

E.39.2. Changes

- Restore GIN metapages unconditionally to avoid torn-page risk (Heikki Linnakangas)

  Although this oversight could theoretically result in a corrupted index, it is unlikely to have caused any problems in practice, since the active part of a GIN metapage is smaller than a standard 512-byte disk sector.

- Avoid race condition in checking transaction commit status during receipt of a `NOTIFY` message (Marko Tiikkaja)

  This prevents a scenario wherein a sufficiently fast client might respond to a notification before database updates made by the notifier have become visible to the recipient.

- Allow regular-expression operators to be terminated early by query cancel requests (Tom Lane)

  This prevents scenarios wherein a pathological regular expression could lock up a server process uninterruptably for a long time.

- Remove incorrect code that tried to allow `OVERLAPS` with single-element row arguments (Joshua Yanovski)

  This code never worked correctly, and since the case is neither specified by the SQL standard nor documented, it seemed better to remove it than fix it.

- Avoid getting more than `AccessShareLock` when de-parsing a rule or view (Dean Rasheed)

  This oversight resulted in pg_dump unexpectedly acquiring `RowExclusiveLock` locks on tables mentioned as the targets of `INSERT`/`UPDATE`/`DELETE` commands in rules. While usually harmless, that could interfere with concurrent transactions that tried to acquire, for example, `ShareLock` on those tables.

- Improve performance of index endpoint probes during planning (Tom Lane)

  This change fixes a significant performance problem that occurred when there were many not-yet-committed rows at the end of the index, which is a common situation for indexes on sequentially-assigned values such as timestamps or sequence-generated identifiers.

- Fix test to see if hot standby connections can be allowed immediately after a crash (Heikki Linnakangas)

- Prevent interrupts while reporting non-`ERROR` messages (Tom Lane)

  This guards against rare server-process freezeups due to recursive entry to `syslog()`, and perhaps other related problems.

- Prevent intermittent "could not reserve shared memory region" failures on recent Windows versions (MauMau)

- Update time zone data files to tzdata release 2014a for DST law changes in Fiji and Turkey, plus historical changes in Israel and Ukraine.

E.40. Release 9.0.16

Release Date: 2014-02-20

This release contains a variety of fixes from 9.0.15. For information about new features in the 9.0 major release, see Section E.56.

E.40.1. Migration to Version 9.0.16

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.15, see Section E.41.

E.40.2. Changes

- Shore up `GRANT ... WITH ADMIN OPTION` restrictions (Noah Misch)

  Granting a role without `ADMIN OPTION` is supposed to prevent the grantee from adding or removing members from the granted role, but this restriction was easily bypassed by doing `SET ROLE` first. The security impact is mostly that a role member can revoke the access of others, contrary to the wishes of his grantor. Unapproved role member additions are a lesser concern, since an uncooperative role member could provide most of his rights to others anyway by creating views or `SECURITY DEFINER` functions. (CVE-2014-0060)

- Prevent privilege escalation via manual calls to PL validator functions (Andres Freund)

  The primary role of PL validator functions is to be called implicitly during `CREATE FUNCTION`, but they are also normal SQL functions that a user can call explicitly. Calling a validator on a function actually written in some other language was not checked for and could be exploited for privilege-escalation purposes. The fix involves adding a call to a privilege-checking function in each validator function. Non-core procedural languages will also need to make this change to their own validator functions, if any. (CVE-2014-0061)

- Avoid multiple name lookups during table and index DDL (Robert Haas, Andres Freund)

  If the name lookups come to different conclusions due to concurrent activity, we might perform some parts of the DDL on a different table than other parts. At least in the case of `CREATE INDEX`, this can be used to cause the permissions checks to be performed against a different table than the index creation, allowing for a privilege escalation attack. (CVE-2014-0062)

- Prevent buffer overrun with long datetime strings (Noah Misch)

  The `MAXDATELEN` constant was too small for the longest possible value of type `interval`, allowing a buffer overrun in `interval_out()`. Although the datetime input functions were more careful about avoiding buffer overrun, the limit was short enough to cause them to reject some valid inputs, such as input containing a very long timezone name. The ecpg library contained these vulnerabilities along with some of its own. (CVE-2014-0063)

- Prevent buffer overrun due to integer overflow in size calculations (Noah Misch, Heikki Linnakangas)

  Several functions, mostly type input functions, calculated an allocation size without checking for overflow. If overflow did occur, a too-small buffer would be allocated and then written past. (CVE-2014-0064)

- Prevent overruns of fixed-size buffers (Peter Eisentraut, Jozef Mlich)

  Use `strlcpy()` and related functions to provide a clear guarantee that fixed-size buffers are not overrun. Unlike the preceding items, it is unclear whether these cases really represent live issues, since in most cases there appear to be previous constraints on the size of the input string. Nonetheless it seems prudent to silence all Coverity warnings of this type. (CVE-2014-0065)

- Avoid crashing if `crypt()` returns NULL (Honza Horak, Bruce Momjian)

  There are relatively few scenarios in which `crypt()` could return NULL, but `contrib/chkpass` would crash if it did. One practical case in which this could be an issue is if libc is configured to refuse to execute unapproved hashing algorithms (e.g., "FIPS mode"). (CVE-2014-0066)

- Document risks of `make check` in the regression testing instructions (Noah Misch, Tom Lane)

  Since the temporary server started by `make check` uses "trust" authentication, another user on the same machine could connect to it as database superuser, and then potentially exploit the privileges of the operating-system user who started the tests. A future release will probably incorporate changes in the testing procedure to prevent this risk, but some public discussion is needed first. So for the moment, just warn people against using `make check` when there are untrusted users on the same machine. (CVE-2014-0067)

- Fix possible mis-replay of WAL records when some segments of a relation aren't full size (Greg Stark, Tom Lane)

  The WAL update could be applied to the wrong page, potentially many pages past where it should have been. Aside from corrupting data, this error has been observed to result in significant "bloat" of standby servers compared to their masters, due to updates being applied far beyond where the end-of-file should have been. This failure mode does not appear to be a significant risk during crash recovery, only when initially synchronizing a standby created from a base backup taken from a quickly-changing master.

- Fix bug in determining when recovery has reached consistency (Tomonari Katsumata, Heikki Linnakangas)

  In some cases WAL replay would mistakenly conclude that the database was already consistent at the start of replay, thus possibly allowing hot-standby queries before the database was really consistent. Other symptoms such as "PANIC: WAL contains references to invalid pages" were also possible.

- Fix improper locking of btree index pages while replaying a `VACUUM` operation in hot-standby mode (Andres Freund, Heikki Linnakangas, Tom Lane)

  This error could result in "PANIC: WAL contains references to invalid pages" failures.

- Ensure that insertions into non-leaf GIN index pages write a full-page WAL record when appropriate (Heikki Linnakangas)

  The previous coding risked index corruption in the event of a partial-page write during a system crash.

- Fix race conditions during server process exit (Robert Haas)

  Ensure that signal handlers don't attempt to use the process's `MyProc` pointer after it's no longer valid.

- Fix unsafe references to `errno` within error reporting logic (Christian Kruse)

  This would typically lead to odd behaviors such as missing or inappropriate `HINT` fields.

- Fix possible crashes from using `ereport()` too early during server startup (Tom Lane)

  The principal case we've seen in the field is a crash if the server is started in a directory it doesn't have permission to read.

- Clear retry flags properly in OpenSSL socket write function (Alexander Kukushkin)

  This omission could result in a server lockup after unexpected loss of an SSL-encrypted connection.

- Fix length checking for Unicode identifiers (`U&"..."` syntax) containing escapes (Tom Lane)

  A spurious truncation warning would be printed for such identifiers if the escaped form of the identifier was too long, but the identifier actually didn't need truncation after de-escaping.

- Allow keywords that are type names to be used in lists of roles (Stephen Frost)

  A previous patch allowed such keywords to be used without quoting in places such as role identifiers; but it missed cases where a list of role identifiers was permitted, such as `DROP ROLE`.

- Fix possible crash due to invalid plan for nested sub-selects, such as `WHERE (... x IN (SELECT ...) ...) IN (SELECT ...)` (Tom Lane)

- Ensure that `ANALYZE` creates statistics for a table column even when all the values in it are "too wide" (Tom Lane)

  `ANALYZE` intentionally omits very wide values from its histogram and most-common-values calculations, but it neglected to do something sane in the case that all the sampled entries are too wide.

- In `ALTER TABLE ... SET TABLESPACE`, allow the database's default tablespace to be used without a permissions check (Stephen Frost)

  `CREATE TABLE` has always allowed such usage, but `ALTER TABLE` didn't get the memo.

- Fix "cannot accept a set" error when some arms of a `CASE` return a set and others don't (Tom Lane)

- Fix checks for all-zero client addresses in pgstat functions (Kevin Grittner)

- Fix possible misclassification of multibyte characters by the text search parser (Tom Lane)

  Non-ASCII characters could be misclassified when using C locale with a multibyte encoding. On Cygwin, non-C locales could fail as well.

- Fix possible misbehavior in `plainto_tsquery()` (Heikki Linnakangas)

  Use `memmove()` not `memcpy()` for copying overlapping memory regions. There have been no field reports of this actually causing trouble, but it's certainly risky.

- Accept `SHIFT_JIS` as an encoding name for locale checking purposes (Tatsuo Ishii)

- Fix misbehavior of `PQhost()` on Windows (Fujii Masao)

  It should return `localhost` if no host has been specified.

- Improve error handling in libpq and psql for failures during `COPY TO STDOUT/FROM STDIN` (Tom Lane)

  In particular this fixes an infinite loop that could occur in 9.2 and up if the server connection was lost during `COPY FROM STDIN`. Variants of that scenario might be possible in older versions, or with other client applications.

- Fix misaligned descriptors in ecpg (MauMau)

- In ecpg, handle lack of a hostname in the connection parameters properly (Michael Meskes)

- Fix performance regression in `contrib/dblink` connection startup (Joe Conway)

  Avoid an unnecessary round trip when client and server encodings match.

- In `contrib/isn`, fix incorrect calculation of the check digit for ISMN values (Fabien Coelho)
- Ensure client-code-only installation procedure works as documented (Peter Eisentraut)
- In Mingw and Cygwin builds, install the libpq DLL in the `bin` directory (Andrew Dunstan)

  This duplicates what the MSVC build has long done. It should fix problems with programs like psql failing to start because they can't find the DLL.

- Avoid using the deprecated `dllwrap` tool in Cygwin builds (Marco Atzeri)
- Don't generate plain-text `HISTORY` and `src/test/regress/README` files anymore (Tom Lane)

  These text files duplicated the main HTML and PDF documentation formats. The trouble involved in maintaining them greatly outweighs the likely audience for plain-text format. Distribution tarballs will still contain files by these names, but they'll just be stubs directing the reader to consult the main documentation. The plain-text `INSTALL` file will still be maintained, as there is arguably a use-case for that.

- Update time zone data files to tzdata release 2013i for DST law changes in Jordan and historical changes in Cuba.

  In addition, the zones `Asia/Riyadh87`, `Asia/Riyadh88`, and `Asia/Riyadh89` have been removed, as they are no longer maintained by IANA, and never represented actual civil timekeeping practice.

E.41. Release 9.0.15

Release Date: 2013-12-05

This release contains a variety of fixes from 9.0.14. For information about new features in the 9.0 major release, see Section E.56.

E.41.1. Migration to Version 9.0.15

A dump/restore is not required for those running 9.0.X.

However, this release corrects a number of potential data corruption issues. See the first two changelog entries below to find out whether your installation has been affected and what steps you can take if so.

Also, if you are upgrading from a version earlier than 9.0.13, see Section E.43.

E.41.2. Changes

- Fix `VACUUM`'s tests to see whether it can update `relfrozenxid` (Andres Freund)

  In some cases `VACUUM` (either manual or autovacuum) could incorrectly advance a table's `relfrozenxid` value, allowing tuples to escape freezing, causing those rows to become invisible once 2^31 transactions have elapsed. The probability of data loss is fairly low since multiple

incorrect advancements would need to happen before actual loss occurs, but it's not zero. Users upgrading from releases 9.0.4 or 8.4.8 or earlier are not affected, but all later versions contain the bug.

The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix any latent corruption but will not be able to fix all pre-existing data errors. However, an installation can be presumed safe after performing this vacuuming if it has executed fewer than 2^31 update transactions in its lifetime (check this with `SELECT txid_current() < 2^31`).

- Fix initialization of `pg_clog` and `pg_subtrans` during hot standby startup (Andres Freund, Heikki Linnakangas)

  This bug can cause data loss on standby servers at the moment they start to accept hot-standby queries, by marking committed transactions as uncommitted. The likelihood of such corruption is small unless, at the time of standby startup, the primary server has executed many updating transactions since its last checkpoint. Symptoms include missing rows, rows that should have been deleted being still visible, and obsolete versions of updated rows being still visible alongside their newer versions.

  This bug was introduced in versions 9.3.0, 9.2.5, 9.1.10, and 9.0.14. Standby servers that have only been running earlier releases are not at risk. It's recommended that standby servers that have ever run any of the buggy releases be re-cloned from the primary (e.g., with a new base backup) after upgrading.

- Truncate `pg_multixact` contents during WAL replay (Andres Freund)

  This avoids ever-increasing disk space consumption in standby servers.

- Fix race condition in GIN index posting tree page deletion (Heikki Linnakangas)

  This could lead to transient wrong answers or query failures.

- Avoid flattening a subquery whose `SELECT` list contains a volatile function wrapped inside a sub-`SELECT` (Tom Lane)

  This avoids unexpected results due to extra evaluations of the volatile function.

- Fix planner's processing of non-simple-variable subquery outputs nested within outer joins (Tom Lane)

  This error could lead to incorrect plans for queries involving multiple levels of subqueries within `JOIN` syntax.

- Fix premature deletion of temporary files (Andres Freund)

- Fix possible read past end of memory in rule printing (Peter Eisentraut)

- Fix array slicing of `int2vector` and `oidvector` values (Tom Lane)

  Expressions of this kind are now implicitly promoted to regular `int2` or `oid` arrays.

- Fix incorrect behaviors when using a SQL-standard, simple GMT offset timezone (Tom Lane)

  In some cases, the system would use the simple GMT offset value when it should have used the regular timezone setting that had prevailed before the simple offset was selected. This change also causes the `timeofday` function to honor the simple GMT offset zone.

- Prevent possible misbehavior when logging translations of Windows error codes (Tom Lane)

- Properly quote generated command lines in pg_ctl (Naoya Anzai and Tom Lane)

  This fix applies only to Windows.

- Fix pg_dumpall to work when a source database sets `default_transaction_read_only` via `ALTER DATABASE SET` (Kevin Grittner)

  Previously, the generated script would fail during restore.
- Fix ecpg's processing of lists of variables declared `varchar` (Zoltán Böszörményi)
- Make `contrib/lo` defend against incorrect trigger definitions (Marc Cousin)
- Update time zone data files to tzdata release 2013h for DST law changes in Argentina, Brazil, Jordan, Libya, Liechtenstein, Morocco, and Palestine. Also, new timezone abbreviations WIB, WIT, WITA for Indonesia.

E.42. Release 9.0.14

Release Date: 2013-10-10

This release contains a variety of fixes from 9.0.13. For information about new features in the 9.0 major release, see Section E.56.

E.42.1. Migration to Version 9.0.14

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.13, see Section E.43.

E.42.2. Changes

- Prevent corruption of multi-byte characters when attempting to case-fold identifiers (Andrew Dunstan)

  PostgreSQL case-folds non-ASCII characters only when using a single-byte server encoding.
- Fix checkpoint memory leak in background writer when `wal_level = hot_standby` (Naoya Anzai)
- Fix memory leak caused by `lo_open()` failure (Heikki Linnakangas)
- Fix memory overcommit bug when `work_mem` is using more than 24GB of memory (Stephen Frost)
- Fix deadlock bug in libpq when using SSL (Stephen Frost)
- Fix possible SSL state corruption in threaded libpq applications (Nick Phillips, Stephen Frost)
- Properly compute row estimates for boolean columns containing many NULL values (Andrew Gierth)

  Previously tests like `col IS NOT TRUE` and `col IS NOT FALSE` did not properly factor in NULL values when estimating plan costs.
- Prevent pushing down `WHERE` clauses into unsafe `UNION/INTERSECT` subqueries (Tom Lane)

Subqueries of a UNION or INTERSECT that contain set-returning functions or volatile functions in their SELECT lists could be improperly optimized, leading to run-time errors or incorrect query results.

- Fix rare case of "failed to locate grouping columns" planner failure (Tom Lane)
- Improve view dumping code's handling of dropped columns in referenced tables (Tom Lane)
- Properly record index comments created using UNIQUE and PRIMARY KEY syntax (Andres Freund)

  This fixes a parallel pg_restore failure.
- Fix REINDEX TABLE and REINDEX DATABASE to properly revalidate constraints and mark invalidated indexes as valid (Noah Misch)

  REINDEX INDEX has always worked properly.
- Fix possible deadlock during concurrent CREATE INDEX CONCURRENTLY operations (Tom Lane)
- Fix regexp_matches() handling of zero-length matches (Jeevan Chalke)

  Previously, zero-length matches like '^' could return too many matches.
- Fix crash for overly-complex regular expressions (Heikki Linnakangas)
- Fix regular expression match failures for back references combined with non-greedy quantifiers (Jeevan Chalke)
- Prevent CREATE FUNCTION from checking SET variables unless function body checking is enabled (Tom Lane)
- Allow ALTER DEFAULT PRIVILEGES to operate on schemas without requiring CREATE permission (Tom Lane)
- Loosen restriction on keywords used in queries (Tom Lane)

  Specifically, lessen keyword restrictions for role names, language names, EXPLAIN and COPY options, and SET values. This allows COPY ... (FORMAT BINARY) to work as expected; previously BINARY needed to be quoted.
- Fix pgp_pub_decrypt() so it works for secret keys with passwords (Marko Kreen)
- Remove rare inaccurate warning during vacuum of index-less tables (Heikki Linnakangas)
- Ensure that VACUUM ANALYZE still runs the ANALYZE phase if its attempt to truncate the file is cancelled due to lock conflicts (Kevin Grittner)
- Avoid possible failure when performing transaction control commands (e.g ROLLBACK) in prepared queries (Tom Lane)
- Ensure that floating-point data input accepts standard spellings of "infinity" on all platforms (Tom Lane)

  The C99 standard says that allowable spellings are inf, +inf, -inf, infinity, +infinity, and -infinity. Make sure we recognize these even if the platform's strtod function doesn't.
- Expand ability to compare rows to records and arrays (Rafal Rzepecki, Tom Lane)
- Update time zone data files to tzdata release 2013d for DST law changes in Israel, Morocco, Palestine, and Paraguay. Also, historical zone data corrections for Macquarie Island.

E.43. Release 9.0.13

Release Date: 2013-04-04

This release contains a variety of fixes from 9.0.12. For information about new features in the 9.0 major release, see Section E.56.

E.43.1. Migration to Version 9.0.13

A dump/restore is not required for those running 9.0.X.

However, this release corrects several errors in management of GiST indexes. After installing this update, it is advisable to `REINDEX` any GiST indexes that meet one or more of the conditions described below.

Also, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.43.2. Changes

- Fix insecure parsing of server command-line switches (Mitsumasa Kondo, Kyotaro Horiguchi)

  A connection request containing a database name that begins with "–" could be crafted to damage or destroy files within the server's data directory, even if the request is eventually rejected. (CVE-2013-1899)

- Reset OpenSSL randomness state in each postmaster child process (Marko Kreen)

  This avoids a scenario wherein random numbers generated by `contrib/pgcrypto` functions might be relatively easy for another database user to guess. The risk is only significant when the postmaster is configured with `ssl = on` but most connections don't use SSL encryption. (CVE-2013-1900)

- Fix GiST indexes to not use "fuzzy" geometric comparisons when it's not appropriate to do so (Alexander Korotkov)

  The core geometric types perform comparisons using "fuzzy" equality, but `gist_box_same` must do exact comparisons, else GiST indexes using it might become inconsistent. After installing this update, users should `REINDEX` any GiST indexes on `box`, `polygon`, `circle`, or `point` columns, since all of these use `gist_box_same`.

- Fix erroneous range-union and penalty logic in GiST indexes that use `contrib/btree_gist` for variable-width data types, that is `text`, `bytea`, `bit`, and `numeric` columns (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in useless index bloat. Users are advised to `REINDEX` such indexes after installing this update.

- Fix bugs in GiST page splitting code for multi-column indexes (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in indexes that are unnecessarily inefficient to search. Users are advised to `REINDEX` multi-column GiST indexes after installing this update.

- Fix `gist_point_consistent` to handle fuzziness consistently (Alexander Korotkov)

Index scans on GiST indexes on `point` columns would sometimes yield results different from a sequential scan, because `gist_point_consistent` disagreed with the underlying operator code about whether to do comparisons exactly or fuzzily.

- Fix buffer leak in WAL replay (Heikki Linnakangas)

  This bug could result in "incorrect local pin count" errors during replay, making recovery impossible.

- Fix race condition in `DELETE RETURNING` (Tom Lane)

  Under the right circumstances, `DELETE RETURNING` could attempt to fetch data from a shared buffer that the current process no longer has any pin on. If some other process changed the buffer meanwhile, this would lead to garbage `RETURNING` output, or even a crash.

- Fix infinite-loop risk in regular expression compilation (Tom Lane, Don Porter)

- Fix potential null-pointer dereference in regular expression compilation (Tom Lane)

- Fix `to_char()` to use ASCII-only case-folding rules where appropriate (Tom Lane)

  This fixes misbehavior of some template patterns that should be locale-independent, but mishandled "`I`" and "`i`" in Turkish locales.

- Fix unwanted rejection of timestamp `1999-12-31 24:00:00` (Tom Lane)

- Fix logic error when a single transaction does `UNLISTEN` then `LISTEN` (Tom Lane)

  The session wound up not listening for notify events at all, though it surely should listen in this case.

- Remove useless "picksplit doesn't support secondary split" log messages (Josh Hansen, Tom Lane)

  This message seems to have been added in expectation of code that was never written, and probably never will be, since GiST's default handling of secondary splits is actually pretty good. So stop nagging end users about it.

- Fix possible failure to send a session's last few transaction commit/abort counts to the statistics collector (Tom Lane)

- Eliminate memory leaks in PL/Perl's `spi_prepare()` function (Alex Hunsaker, Tom Lane)

- Fix pg_dumpall to handle database names containing "=" correctly (Heikki Linnakangas)

- Avoid crash in pg_dump when an incorrect connection string is given (Heikki Linnakangas)

- Ignore invalid indexes in pg_dump and pg_upgrade (Michael Paquier, Bruce Momjian)

  Dumping invalid indexes can cause problems at restore time, for example if the reason the index creation failed was because it tried to enforce a uniqueness condition not satisfied by the table's data. Also, if the index creation is in fact still in progress, it seems reasonable to consider it to be an uncommitted DDL change, which pg_dump wouldn't be expected to dump anyway. pg_upgrade now also skips invalid indexes rather than failing.

- Fix `contrib/pg_trgm`'s `similarity()` function to return zero for trigram-less strings (Tom Lane)

  Previously it returned `NaN` due to internal division by zero.

- Update time zone data files to tzdata release 2013b for DST law changes in Chile, Haiti, Morocco, Paraguay, and some Russian areas. Also, historical zone data corrections for numerous places.

  Also, update the time zone abbreviation files for recent changes in Russia and elsewhere: `CHOT`, `GET`, `IRKT`, `KGT`, `KRAT`, `MAGT`, `MAWT`, `MSK`, `NOVT`, `OMST`, `TKT`, `VLAT`, `WST`, `YAKT`, `YEKT` now follow their current meanings, and `VOLT` (Europe/Volgograd) and `MIST` (Antarctica/Macquarie) are added to the default abbreviations list.

E.44. Release 9.0.12

Release Date: 2013-02-07

This release contains a variety of fixes from 9.0.11. For information about new features in the 9.0 major release, see Section E.56.

E.44.1. Migration to Version 9.0.12

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.44.2. Changes

- Prevent execution of `enum_recv` from SQL (Tom Lane)

  The function was misdeclared, allowing a simple SQL command to crash the server. In principle an attacker might be able to use it to examine the contents of server memory. Our thanks to Sumit Soni (via Secunia SVCRP) for reporting this issue. (CVE-2013-0255)

- Fix multiple problems in detection of when a consistent database state has been reached during WAL replay (Fujii Masao, Heikki Linnakangas, Simon Riggs, Andres Freund)

- Update minimum recovery point when truncating a relation file (Heikki Linnakangas)

  Once data has been discarded, it's no longer safe to stop recovery at an earlier point in the timeline.

- Fix missing cancellations in hot standby mode (Noah Misch, Simon Riggs)

  The need to cancel conflicting hot-standby queries would sometimes be missed, allowing those queries to see inconsistent data.

- Fix SQL grammar to allow subscripting or field selection from a sub-SELECT result (Tom Lane)

- Fix performance problems with autovacuum truncation in busy workloads (Jan Wieck)

  Truncation of empty pages at the end of a table requires exclusive lock, but autovacuum was coded to fail (and release the table lock) when there are conflicting lock requests. Under load, it is easily possible that truncation would never occur, resulting in table bloat. Fix by performing a partial truncation, releasing the lock, then attempting to re-acquire the lock and continue. This fix also greatly reduces the average time before autovacuum releases the lock after a conflicting request arrives.

- Protect against race conditions when scanning `pg_tablespace` (Stephen Frost, Tom Lane)

  `CREATE DATABASE` and `DROP DATABASE` could misbehave if there were concurrent updates of `pg_tablespace` entries.

- Prevent `DROP OWNED` from trying to drop whole databases or tablespaces (Álvaro Herrera)

  For safety, ownership of these objects must be reassigned, not dropped.

- Fix error in `vacuum_freeze_table_age` implementation (Andres Freund)

In installations that have existed for more than `vacuum_freeze_min_age` transactions, this mistake prevented autovacuum from using partial-table scans, so that a full-table scan would always happen instead.

- Prevent misbehavior when a `RowExpr` or `XmlExpr` is parse-analyzed twice (Andres Freund, Tom Lane)

  This mistake could be user-visible in contexts such as `CREATE TABLE LIKE INCLUDING INDEXES`.

- Improve defenses against integer overflow in hashtable sizing calculations (Jeff Davis)
- Reject out-of-range dates in `to_date()` (Hitoshi Harada)
- Ensure that non-ASCII prompt strings are translated to the correct code page on Windows (Alexander Law, Noah Misch)

  This bug affected psql and some other client programs.

- Fix possible crash in psql's `\?` command when not connected to a database (Meng Qingzhong)
- Fix pg_upgrade to deal with invalid indexes safely (Bruce Momjian)
- Fix one-byte buffer overrun in libpq's `PQprintTuples` (Xi Wang)

  This ancient function is not used anywhere by PostgreSQL itself, but it might still be used by some client code.

- Make ecpglib use translated messages properly (Chen Huajun)
- Properly install ecpg_compat and pgtypes libraries on MSVC (Jiang Guiqing)
- Include our version of `isinf()` in libecpg if it's not provided by the system (Jiang Guiqing)
- Rearrange configure's tests for supplied functions so it is not fooled by bogus exports from libedit/libreadline (Christoph Berg)
- Ensure Windows build number increases over time (Magnus Hagander)
- Make pgxs build executables with the right `.exe` suffix when cross-compiling for Windows (Zoltan Boszormenyi)
- Add new timezone abbreviation `FET` (Tom Lane)

  This is now used in some eastern-European time zones.

E.45. Release 9.0.11

Release Date: 2012-12-06

This release contains a variety of fixes from 9.0.10. For information about new features in the 9.0 major release, see Section E.56.

E.45.1. Migration to Version 9.0.11

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.45.2. Changes

- Fix multiple bugs associated with `CREATE INDEX CONCURRENTLY` (Andres Freund, Tom Lane)

  Fix `CREATE INDEX CONCURRENTLY` to use in-place updates when changing the state of an index's `pg_index` row. This prevents race conditions that could cause concurrent sessions to miss updating the target index, thus resulting in corrupt concurrently-created indexes.

  Also, fix various other operations to ensure that they ignore invalid indexes resulting from a failed `CREATE INDEX CONCURRENTLY` command. The most important of these is `VACUUM`, because an auto-vacuum could easily be launched on the table before corrective action can be taken to fix or remove the invalid index.

- Fix buffer locking during WAL replay (Tom Lane)

  The WAL replay code was insufficiently careful about locking buffers when replaying WAL records that affect more than one page. This could result in hot standby queries transiently seeing inconsistent states, resulting in wrong answers or unexpected failures.

- Fix an error in WAL generation logic for GIN indexes (Tom Lane)

  This could result in index corruption, if a torn-page failure occurred.

- Properly remove startup process's virtual XID lock when promoting a hot standby server to normal running (Simon Riggs)

  This oversight could prevent subsequent execution of certain operations such as `CREATE INDEX CONCURRENTLY`.

- Avoid bogus "out-of-sequence timeline ID" errors in standby mode (Heikki Linnakangas)

- Prevent the postmaster from launching new child processes after it's received a shutdown signal (Tom Lane)

  This mistake could result in shutdown taking longer than it should, or even never completing at all without additional user action.

- Avoid corruption of internal hash tables when out of memory (Hitoshi Harada)

- Fix planning of non-strict equivalence clauses above outer joins (Tom Lane)

  The planner could derive incorrect constraints from a clause equating a non-strict construct to something else, for example `WHERE COALESCE(foo, 0) = 0` when `foo` is coming from the nullable side of an outer join.

- Improve planner's ability to prove exclusion constraints from equivalence classes (Tom Lane)

- Fix partial-row matching in hashed subplans to handle cross-type cases correctly (Tom Lane)

  This affects multicolumn `NOT IN` subplans, such as `WHERE (a, b) NOT IN (SELECT x, y FROM ...)` when for instance `b` and `y` are `int4` and `int8` respectively. This mistake led to wrong answers or crashes depending on the specific datatypes involved.

- Acquire buffer lock when re-fetching the old tuple for an `AFTER ROW UPDATE/DELETE` trigger (Andres Freund)

  In very unusual circumstances, this oversight could result in passing incorrect data to the precheck logic for a foreign-key enforcement trigger. That could result in a crash, or in an incorrect decision about whether to fire the trigger.

- Fix `ALTER COLUMN TYPE` to handle inherited check constraints properly (Pavan Deolasee)

  This worked correctly in pre-8.4 releases, and now works correctly in 8.4 and later.

- Fix `REASSIGN OWNED` to handle grants on tablespaces (Álvaro Herrera)
- Ignore incorrect `pg_attribute` entries for system columns for views (Tom Lane)

  Views do not have any system columns. However, we forgot to remove such entries when converting a table to a view. That's fixed properly for 9.3 and later, but in previous branches we need to defend against existing mis-converted views.
- Fix rule printing to dump `INSERT INTO` *`table`* `DEFAULT VALUES` correctly (Tom Lane)
- Guard against stack overflow when there are too many `UNION`/`INTERSECT`/`EXCEPT` clauses in a query (Tom Lane)
- Prevent platform-dependent failures when dividing the minimum possible integer value by -1 (Xi Wang, Tom Lane)
- Fix possible access past end of string in date parsing (Hitoshi Harada)
- Fix failure to advance XID epoch if XID wraparound happens during a checkpoint and `wal_level` is `hot_standby` (Tom Lane, Andres Freund)

  While this mistake had no particular impact on PostgreSQL itself, it was bad for applications that rely on `txid_current()` and related functions: the TXID value would appear to go backwards.
- Produce an understandable error message if the length of the path name for a Unix-domain socket exceeds the platform-specific limit (Tom Lane, Andrew Dunstan)

  Formerly, this would result in something quite unhelpful, such as "Non-recoverable failure in name resolution".
- Fix memory leaks when sending composite column values to the client (Tom Lane)
- Make pg_ctl more robust about reading the `postmaster.pid` file (Heikki Linnakangas)

  Fix race conditions and possible file descriptor leakage.
- Fix possible crash in psql if incorrectly-encoded data is presented and the `client_encoding` setting is a client-only encoding, such as SJIS (Jiang Guiqing)
- Fix bugs in the `restore.sql` script emitted by pg_dump in `tar` output format (Tom Lane)

  The script would fail outright on tables whose names include upper-case characters. Also, make the script capable of restoring data in `--inserts` mode as well as the regular COPY mode.
- Fix pg_restore to accept POSIX-conformant `tar` files (Brian Weaver, Tom Lane)

  The original coding of pg_dump's `tar` output mode produced files that are not fully conformant with the POSIX standard. This has been corrected for version 9.3. This patch updates previous branches so that they will accept both the incorrect and the corrected formats, in hopes of avoiding compatibility problems when 9.3 comes out.
- Fix pg_resetxlog to locate `postmaster.pid` correctly when given a relative path to the data directory (Tom Lane)

  This mistake could lead to pg_resetxlog not noticing that there is an active postmaster using the data directory.
- Fix libpq's `lo_import()` and `lo_export()` functions to report file I/O errors properly (Tom Lane)
- Fix ecpg's processing of nested structure pointer variables (Muhammad Usama)
- Fix ecpg's `ecpg_get_data` function to handle arrays properly (Michael Meskes)
- Make `contrib/pageinspect`'s btree page inspection functions take buffer locks while examining pages (Tom Lane)

- Fix pgxs support for building loadable modules on AIX (Tom Lane)

  Building modules outside the original source tree didn't work on AIX.

- Update time zone data files to tzdata release 2012j for DST law changes in Cuba, Israel, Jordan, Libya, Palestine, Western Samoa, and portions of Brazil.

E.46. Release 9.0.10

Release Date: 2012-09-24

This release contains a variety of fixes from 9.0.9. For information about new features in the 9.0 major release, see Section E.56.

E.46.1. Migration to Version 9.0.10

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.46.2. Changes

- Fix planner's assignment of executor parameters, and fix executor's rescan logic for CTE plan nodes (Tom Lane)

  These errors could result in wrong answers from queries that scan the same `WITH` subquery multiple times.

- Improve page-splitting decisions in GiST indexes (Alexander Korotkov, Robert Haas, Tom Lane)

  Multi-column GiST indexes might suffer unexpected bloat due to this error.

- Fix cascading privilege revoke to stop if privileges are still held (Tom Lane)

  If we revoke a grant option from some role *X*, but *X* still holds that option via a grant from someone else, we should not recursively revoke the corresponding privilege from role(s) *Y* that *X* had granted it to.

- Improve error messages for Hot Standby misconfiguration errors (Gurjeet Singh)

- Fix handling of `SIGFPE` when PL/Perl is in use (Andres Freund)

  Perl resets the process's `SIGFPE` handler to `SIG_IGN`, which could result in crashes later on. Restore the normal Postgres signal handler after initializing PL/Perl.

- Prevent PL/Perl from crashing if a recursive PL/Perl function is redefined while being executed (Tom Lane)

- Work around possible misoptimization in PL/Perl (Tom Lane)

  Some Linux distributions contain an incorrect version of `pthread.h` that results in incorrect compiled code in PL/Perl, leading to crashes if a PL/Perl function calls another one that throws an error.

- Fix pg_upgrade's handling of line endings on Windows (Andrew Dunstan)

  Previously, pg_upgrade might add or remove carriage returns in places such as function bodies.

- On Windows, make pg_upgrade use backslash path separators in the scripts it emits (Andrew Dunstan)

- Update time zone data files to tzdata release 2012f for DST law changes in Fiji

E.47. Release 9.0.9

Release Date: 2012-08-17

This release contains a variety of fixes from 9.0.8. For information about new features in the 9.0 major release, see Section E.56.

E.47.1. Migration to Version 9.0.9

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.47.2. Changes

- Prevent access to external files/URLs via XML entity references (Noah Misch, Tom Lane)

  `xml_parse()` would attempt to fetch external files or URLs as needed to resolve DTD and entity references in an XML value, thus allowing unprivileged database users to attempt to fetch data with the privileges of the database server. While the external data wouldn't get returned directly to the user, portions of it could be exposed in error messages if the data didn't parse as valid XML; and in any case the mere ability to check existence of a file might be useful to an attacker. (CVE-2012-3489)

- Prevent access to external files/URLs via `contrib/xml2`'s `xslt_process()` (Peter Eisentraut)

  libxslt offers the ability to read and write both files and URLs through stylesheet commands, thus allowing unprivileged database users to both read and write data with the privileges of the database server. Disable that through proper use of libxslt's security options. (CVE-2012-3488)

  Also, remove `xslt_process()`'s ability to fetch documents and stylesheets from external files/URLs. While this was a documented "feature", it was long regarded as a bad idea. The fix for CVE-2012-3489 broke that capability, and rather than expend effort on trying to fix it, we're just going to summarily remove it.

- Prevent too-early recycling of btree index pages (Noah Misch)

  When we allowed read-only transactions to skip assigning XIDs, we introduced the possibility that a deleted btree page could be recycled while a read-only transaction was still in flight to it. This would result in incorrect index search results. The probability of such an error occurring in the field seems very low because of the timing requirements, but nonetheless it should be fixed.

- Fix crash-safety bug with newly-created-or-reset sequences (Tom Lane)

If `ALTER SEQUENCE` was executed on a freshly created or reset sequence, and then precisely one `nextval()` call was made on it, and then the server crashed, WAL replay would restore the sequence to a state in which it appeared that no `nextval()` had been done, thus allowing the first sequence value to be returned again by the next `nextval()` call. In particular this could manifest for `serial` columns, since creation of a serial column's sequence includes an `ALTER SEQUENCE OWNED BY` step.

- Fix `txid_current()` to report the correct epoch when not in hot standby (Heikki Linnakangas)

  This fixes a regression introduced in the previous minor release.

- Fix bug in startup of Hot Standby when a master transaction has many subtransactions (Andres Freund)

  This mistake led to failures reported as "out-of-order XID insertion in KnownAssignedXids".

- Ensure the `backup_label` file is fsync'd after `pg_start_backup()` (Dave Kerr)

- Fix timeout handling in walsender processes (Tom Lane)

  WAL sender background processes neglected to establish a SIGALRM handler, meaning they would wait forever in some corner cases where a timeout ought to happen.

- Back-patch 9.1 improvement to compress the fsync request queue (Robert Haas)

  This improves performance during checkpoints. The 9.1 change has now seen enough field testing to seem safe to back-patch.

- Fix `LISTEN`/`NOTIFY` to cope better with I/O problems, such as out of disk space (Tom Lane)

  After a write failure, all subsequent attempts to send more `NOTIFY` messages would fail with messages like "Could not read from file "pg_notify/*nnnn*" at offset *nnnnn*: Success".

- Only allow autovacuum to be auto-canceled by a directly blocked process (Tom Lane)

  The original coding could allow inconsistent behavior in some cases; in particular, an autovacuum could get canceled after less than `deadlock_timeout` grace period.

- Improve logging of autovacuum cancels (Robert Haas)

- Fix log collector so that `log_truncate_on_rotation` works during the very first log rotation after server start (Tom Lane)

- Fix `WITH` attached to a nested set operation (`UNION`/`INTERSECT`/`EXCEPT`) (Tom Lane)

- Ensure that a whole-row reference to a subquery doesn't include any extra `GROUP BY` or `ORDER BY` columns (Tom Lane)

- Disallow copying whole-row references in `CHECK` constraints and index definitions during `CREATE TABLE` (Tom Lane)

  This situation can arise in `CREATE TABLE` with `LIKE` or `INHERITS`. The copied whole-row variable was incorrectly labeled with the row type of the original table not the new one. Rejecting the case seems reasonable for `LIKE`, since the row types might well diverge later. For `INHERITS` we should ideally allow it, with an implicit coercion to the parent table's row type; but that will require more work than seems safe to back-patch.

- Fix memory leak in `ARRAY(SELECT ...)` subqueries (Heikki Linnakangas, Tom Lane)

- Fix extraction of common prefixes from regular expressions (Tom Lane)

  The code could get confused by quantified parenthesized subexpressions, such as `^(foo)?bar`. This would lead to incorrect index optimization of searches for such patterns.

- Fix bugs with parsing signed *hh*`:`*mm* and *hh*`:`*mm*`:`*ss* fields in `interval` constants (Amit Kapila, Tom Lane)

- Use Postgres' encoding conversion functions, not Python's, when converting a Python Unicode string to the server encoding in PL/Python (Jan Urbanski)

  This avoids some corner-case problems, notably that Python doesn't support all the encodings Postgres does. A notable functional change is that if the server encoding is SQL_ASCII, you will get the UTF-8 representation of the string; formerly, any non-ASCII characters in the string would result in an error.
- Fix mapping of PostgreSQL encodings to Python encodings in PL/Python (Jan Urbanski)
- Report errors properly in `contrib/xml2`'s `xslt_process()` (Tom Lane)
- Update time zone data files to tzdata release 2012e for DST law changes in Morocco and Tokelau

E.48. Release 9.0.8

Release Date: 2012-06-04

This release contains a variety of fixes from 9.0.7. For information about new features in the 9.0 major release, see Section E.56.

E.48.1. Migration to Version 9.0.8

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.48.2. Changes

- Fix incorrect password transformation in `contrib/pgcrypto`'s DES `crypt()` function (Solar Designer)

  If a password string contained the byte value `0x80`, the remainder of the password was ignored, causing the password to be much weaker than it appeared. With this fix, the rest of the string is properly included in the DES hash. Any stored password values that are affected by this bug will thus no longer match, so the stored values may need to be updated. (CVE-2012-2143)
- Ignore `SECURITY DEFINER` and `SET` attributes for a procedural language's call handler (Tom Lane)

  Applying such attributes to a call handler could crash the server. (CVE-2012-2655)
- Allow numeric timezone offsets in `timestamp` input to be up to 16 hours away from UTC (Tom Lane)

  Some historical time zones have offsets larger than 15 hours, the previous limit. This could result in dumped data values being rejected during reload.
- Fix timestamp conversion to cope when the given time is exactly the last DST transition time for the current timezone (Tom Lane)

This oversight has been there a long time, but was not noticed previously because most DST-using zones are presumed to have an indefinite sequence of future DST transitions.

- Fix `text` to `name` and `char` to `name` casts to perform string truncation correctly in multibyte encodings (Karl Schnaitter)
- Fix memory copying bug in `to_tsquery()` (Heikki Linnakangas)
- Ensure `txid_current()` reports the correct epoch when executed in hot standby (Simon Riggs)
- Fix planner's handling of outer PlaceHolderVars within subqueries (Tom Lane)

  This bug concerns sub-SELECTs that reference variables coming from the nullable side of an outer join of the surrounding query. In 9.1, queries affected by this bug would fail with "ERROR: Upper-level PlaceHolderVar found where not expected". But in 9.0 and 8.4, you'd silently get possibly-wrong answers, since the value transmitted into the subquery wouldn't go to null when it should.
- Fix slow session startup when `pg_attribute` is very large (Tom Lane)

  If `pg_attribute` exceeds one-fourth of `shared_buffers`, cache rebuilding code that is sometimes needed during session start would trigger the synchronized-scan logic, causing it to take many times longer than normal. The problem was particularly acute if many new sessions were starting at once.
- Ensure sequential scans check for query cancel reasonably often (Merlin Moncure)

  A scan encountering many consecutive pages that contain no live tuples would not respond to interrupts meanwhile.
- Ensure the Windows implementation of `PGSemaphoreLock()` clears `ImmediateInterruptOK` before returning (Tom Lane)

  This oversight meant that a query-cancel interrupt received later in the same query could be accepted at an unsafe time, with unpredictable but not good consequences.
- Show whole-row variables safely when printing views or rules (Abbas Butt, Tom Lane)

  Corner cases involving ambiguous names (that is, the name could be either a table or column name of the query) were printed in an ambiguous way, risking that the view or rule would be interpreted differently after dump and reload. Avoid the ambiguous case by attaching a no-op cast.
- Fix `COPY FROM` to properly handle null marker strings that correspond to invalid encoding (Tom Lane)

  A null marker string such as `E'\\0'` should work, and did work in the past, but the case got broken in 8.4.
- Ensure autovacuum worker processes perform stack depth checking properly (Heikki Linnakangas)

  Previously, infinite recursion in a function invoked by auto-`ANALYZE` could crash worker processes.
- Fix logging collector to not lose log coherency under high load (Andrew Dunstan)

  The collector previously could fail to reassemble large messages if it got too busy.
- Fix logging collector to ensure it will restart file rotation after receiving SIGHUP (Tom Lane)
- Fix WAL replay logic for GIN indexes to not fail if the index was subsequently dropped (Tom Lane)
- Fix memory leak in PL/pgSQL's `RETURN NEXT` command (Joe Conway)
- Fix PL/pgSQL's `GET DIAGNOSTICS` command when the target is the function's first variable (Tom Lane)

- Fix potential access off the end of memory in psql's expanded display (`\x`) mode (Peter Eisentraut)
- Fix several performance problems in pg_dump when the database contains many objects (Jeff Janes, Tom Lane)

  pg_dump could get very slow if the database contained many schemas, or if many objects are in dependency loops, or if there are many owned sequences.
- Fix pg_upgrade for the case that a database stored in a non-default tablespace contains a table in the cluster's default tablespace (Bruce Momjian)
- In ecpg, fix rare memory leaks and possible overwrite of one byte after the `sqlca_t` structure (Peter Eisentraut)
- Fix `contrib/dblink`'s `dblink_exec()` to not leak temporary database connections upon error (Tom Lane)
- Fix `contrib/dblink` to report the correct connection name in error messages (Kyotaro Horiguchi)
- Fix `contrib/vacuumlo` to use multiple transactions when dropping many large objects (Tim Lewis, Robert Haas, Tom Lane)

  This change avoids exceeding `max_locks_per_transaction` when many objects need to be dropped. The behavior can be adjusted with the new `-l` (limit) option.
- Update time zone data files to tzdata release 2012c for DST law changes in Antarctica, Armenia, Chile, Cuba, Falkland Islands, Gaza, Haiti, Hebron, Morocco, Syria, and Tokelau Islands; also historical corrections for Canada.

E.49. Release 9.0.7

Release Date: 2012-02-27

This release contains a variety of fixes from 9.0.6. For information about new features in the 9.0 major release, see Section E.56.

E.49.1. Migration to Version 9.0.7

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.6, see Section E.50.

E.49.2. Changes

- Require execute permission on the trigger function for `CREATE TRIGGER` (Robert Haas)

  This missing check could allow another user to execute a trigger function with forged input data, by installing it on a table he owns. This is only of significance for trigger functions marked `SECURITY DEFINER`, since otherwise trigger functions run as the table owner anyway. (CVE-2012-0866)
- Remove arbitrary limitation on length of common name in SSL certificates (Heikki Linnakangas)

Both libpq and the server truncated the common name extracted from an SSL certificate at 32 bytes. Normally this would cause nothing worse than an unexpected verification failure, but there are some rather-implausible scenarios in which it might allow one certificate holder to impersonate another. The victim would have to have a common name exactly 32 bytes long, and the attacker would have to persuade a trusted CA to issue a certificate in which the common name has that string as a prefix. Impersonating a server would also require some additional exploit to redirect client connections. (CVE-2012-0867)

- Convert newlines to spaces in names written in pg_dump comments (Robert Haas)

  pg_dump was incautious about sanitizing object names that are emitted within SQL comments in its output script. A name containing a newline would at least render the script syntactically incorrect. Maliciously crafted object names could present a SQL injection risk when the script is reloaded. (CVE-2012-0868)

- Fix btree index corruption from insertions concurrent with vacuuming (Tom Lane)

  An index page split caused by an insertion could sometimes cause a concurrently-running `VACUUM` to miss removing index entries that it should remove. After the corresponding table rows are removed, the dangling index entries would cause errors (such as "could not read block N in file ...") or worse, silently wrong query results after unrelated rows are re-inserted at the now-free table locations. This bug has been present since release 8.2, but occurs so infrequently that it was not diagnosed until now. If you have reason to suspect that it has happened in your database, reindexing the affected index will fix things.

- Fix transient zeroing of shared buffers during WAL replay (Tom Lane)

  The replay logic would sometimes zero and refill a shared buffer, so that the contents were transiently invalid. In hot standby mode this can result in a query that's executing in parallel seeing garbage data. Various symptoms could result from that, but the most common one seems to be "invalid memory alloc request size".

- Fix postmaster to attempt restart after a hot-standby crash (Tom Lane)

  A logic error caused the postmaster to terminate, rather than attempt to restart the cluster, if any backend process crashed while operating in hot standby mode.

- Fix `CLUSTER`/`VACUUM FULL` handling of toast values owned by recently-updated rows (Tom Lane)

  This oversight could lead to "duplicate key value violates unique constraint" errors being reported against the toast table's index during one of these commands.

- Update per-column permissions, not only per-table permissions, when changing table owner (Tom Lane)

  Failure to do this meant that any previously granted column permissions were still shown as having been granted by the old owner. This meant that neither the new owner nor a superuser could revoke the now-untraceable-to-table-owner permissions.

- Support foreign data wrappers and foreign servers in `REASSIGN OWNED` (Alvaro Herrera)

  This command failed with "unexpected classid" errors if it needed to change the ownership of any such objects.

- Allow non-existent values for some settings in `ALTER USER/DATABASE SET` (Heikki Linnakangas)

  Allow `default_text_search_config`, `default_tablespace`, and `temp_tablespaces` to be set to names that are not known. This is because they might be known in another database where the setting is intended to be used, or for the tablespace cases because the tablespace might not be

created yet. The same issue was previously recognized for `search_path`, and these settings now act like that one.

- Avoid crashing when we have problems deleting table files post-commit (Tom Lane)

  Dropping a table should lead to deleting the underlying disk files only after the transaction commits. In event of failure then (for instance, because of wrong file permissions) the code is supposed to just emit a warning message and go on, since it's too late to abort the transaction. This logic got broken as of release 8.4, causing such situations to result in a PANIC and an unrestartable database.

- Recover from errors occurring during WAL replay of `DROP TABLESPACE` (Tom Lane)

  Replay will attempt to remove the tablespace's directories, but there are various reasons why this might fail (for example, incorrect ownership or permissions on those directories). Formerly the replay code would panic, rendering the database unrestartable without manual intervention. It seems better to log the problem and continue, since the only consequence of failure to remove the directories is some wasted disk space.

- Fix race condition in logging AccessExclusiveLocks for hot standby (Simon Riggs)

  Sometimes a lock would be logged as being held by "transaction zero". This is at least known to produce assertion failures on slave servers, and might be the cause of more serious problems.

- Track the OID counter correctly during WAL replay, even when it wraps around (Tom Lane)

  Previously the OID counter would remain stuck at a high value until the system exited replay mode. The practical consequences of that are usually nil, but there are scenarios wherein a standby server that's been promoted to master might take a long time to advance the OID counter to a reasonable value once values are needed.

- Prevent emitting misleading "consistent recovery state reached" log message at the beginning of crash recovery (Heikki Linnakangas)

- Fix initial value of `pg_stat_replication.replay_location` (Fujii Masao)

  Previously, the value shown would be wrong until at least one WAL record had been replayed.

- Fix regular expression back-references with `*` attached (Tom Lane)

  Rather than enforcing an exact string match, the code would effectively accept any string that satisfies the pattern sub-expression referenced by the back-reference symbol.

  A similar problem still afflicts back-references that are embedded in a larger quantified expression, rather than being the immediate subject of the quantifier. This will be addressed in a future PostgreSQL release.

- Fix recently-introduced memory leak in processing of `inet`/`cidr` values (Heikki Linnakangas)

  A patch in the December 2011 releases of PostgreSQL caused memory leakage in these operations, which could be significant in scenarios such as building a btree index on such a column.

- Fix dangling pointer after `CREATE TABLE AS`/`SELECT INTO` in a SQL-language function (Tom Lane)

  In most cases this only led to an assertion failure in assert-enabled builds, but worse consequences seem possible.

- Avoid double close of file handle in syslogger on Windows (MauMau)

  Ordinarily this error was invisible, but it would cause an exception when running on a debug version of Windows.

- Fix I/O-conversion-related memory leaks in plpgsql (Andres Freund, Jan Urbanski, Tom Lane)

  Certain operations would leak memory until the end of the current function.

- Improve pg_dump's handling of inherited table columns (Tom Lane)

  pg_dump mishandled situations where a child column has a different default expression than its parent column. If the default is textually identical to the parent's default, but not actually the same (for instance, because of schema search path differences) it would not be recognized as different, so that after dump and restore the child would be allowed to inherit the parent's default. Child columns that are `NOT NULL` where their parent is not could also be restored subtly incorrectly.

- Fix pg_restore's direct-to-database mode for INSERT-style table data (Tom Lane)

  Direct-to-database restores from archive files made with `--inserts` or `--column-inserts` options fail when using pg_restore from a release dated September or December 2011, as a result of an oversight in a fix for another problem. The archive file itself is not at fault, and text-mode output is okay.

- Allow pg_upgrade to process tables containing `regclass` columns (Bruce Momjian)

  Since pg_upgrade now takes care to preserve `pg_class` OIDs, there was no longer any reason for this restriction.

- Make libpq ignore `ENOTDIR` errors when looking for an SSL client certificate file (Magnus Hagander)

  This allows SSL connections to be established, though without a certificate, even when the user's home directory is set to something like `/dev/null`.

- Fix some more field alignment issues in ecpg's SQLDA area (Zoltan Boszormenyi)

- Allow `AT` option in ecpg `DEALLOCATE` statements (Michael Meskes)

  The infrastructure to support this has been there for awhile, but through an oversight there was still an error check rejecting the case.

- Do not use the variable name when defining a varchar structure in ecpg (Michael Meskes)

- Fix `contrib/auto_explain`'s JSON output mode to produce valid JSON (Andrew Dunstan)

  The output used brackets at the top level, when it should have used braces.

- Fix error in `contrib/intarray`'s `int[] & int[]` operator (Guillaume Lelarge)

  If the smallest integer the two input arrays have in common is 1, and there are smaller values in either array, then 1 would be incorrectly omitted from the result.

- Fix error detection in `contrib/pgcrypto`'s `encrypt_iv()` and `decrypt_iv()` (Marko Kreen)

  These functions failed to report certain types of invalid-input errors, and would instead return random garbage values for incorrect input.

- Fix one-byte buffer overrun in `contrib/test_parser` (Paul Guyot)

  The code would try to read one more byte than it should, which would crash in corner cases. Since `contrib/test_parser` is only example code, this is not a security issue in itself, but bad example code is still bad.

- Use `__sync_lock_test_and_set()` for spinlocks on ARM, if available (Martin Pitt)

  This function replaces our previous use of the `SWPB` instruction, which is deprecated and not available on ARMv6 and later. Reports suggest that the old code doesn't fail in an obvious way on recent ARM boards, but simply doesn't interlock concurrent accesses, leading to bizarre failures in multiprocess operation.

- Use `-fexcess-precision=standard` option when building with gcc versions that accept it (Andrew Dunstan)

  This prevents assorted scenarios wherein recent versions of gcc will produce creative results.

- Allow use of threaded Python on FreeBSD (Chris Rees)

  Our configure script previously believed that this combination wouldn't work; but FreeBSD fixed the problem, so remove that error check.

E.50. Release 9.0.6

Release Date: 2011-12-05

This release contains a variety of fixes from 9.0.5. For information about new features in the 9.0 major release, see Section E.56.

E.50.1. Migration to Version 9.0.6

A dump/restore is not required for those running 9.0.X.

However, a longstanding error was discovered in the definition of the `information_schema.referential_constraints` view. If you rely on correct results from that view, you should replace its definition as explained in the first changelog item below.

Also, if you are upgrading from a version earlier than 9.0.4, see Section E.52.

E.50.2. Changes

- Fix bugs in `information_schema.referential_constraints` view (Tom Lane)

  This view was being insufficiently careful about matching the foreign-key constraint to the depended-on primary or unique key constraint. That could result in failure to show a foreign key constraint at all, or showing it multiple times, or claiming that it depends on a different constraint than the one it really does.

  Since the view definition is installed by initdb, merely upgrading will not fix the problem. If you need to fix this in an existing installation, you can (as a superuser) drop the `information_schema` schema then re-create it by sourcing *`SHAREDIR`*`/information_schema.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) This must be repeated in each database to be fixed.

- Fix possible crash during `UPDATE` or `DELETE` that joins to the output of a scalar-returning function (Tom Lane)

  A crash could only occur if the target row had been concurrently updated, so this problem surfaced only intermittently.

- Fix incorrect replay of WAL records for GIN index updates (Tom Lane)

  This could result in transiently failing to find index entries after a crash, or on a hot-standby server. The problem would be repaired by the next `VACUUM` of the index, however.

- Fix TOAST-related data corruption during `CREATE TABLE dest AS SELECT * FROM src` or `INSERT INTO dest SELECT * FROM src` (Tom Lane)

If a table has been modified by `ALTER TABLE ADD COLUMN`, attempts to copy its data verbatim to another table could produce corrupt results in certain corner cases. The problem can only manifest in this precise form in 8.4 and later, but we patched earlier versions as well in case there are other code paths that could trigger the same bug.

- Fix possible failures during hot standby startup (Simon Riggs)
- Start hot standby faster when initial snapshot is incomplete (Simon Riggs)
- Fix race condition during toast table access from stale syscache entries (Tom Lane)

  The typical symptom was transient errors like "missing chunk number 0 for toast value NNNNN in pg_toast_2619", where the cited toast table would always belong to a system catalog.
- Track dependencies of functions on items used in parameter default expressions (Tom Lane)

  Previously, a referenced object could be dropped without having dropped or modified the function, leading to misbehavior when the function was used. Note that merely installing this update will not fix the missing dependency entries; to do that, you'd need to `CREATE OR REPLACE` each such function afterwards. If you have functions whose defaults depend on non-built-in objects, doing so is recommended.
- Allow inlining of set-returning SQL functions with multiple OUT parameters (Tom Lane)
- Don't trust deferred-unique indexes for join removal (Tom Lane and Marti Raudsepp)

  A deferred uniqueness constraint might not hold intra-transaction, so assuming that it does could give incorrect query results.
- Make `DatumGetInetP()` unpack inet datums that have a 1-byte header, and add a new macro, `DatumGetInetPP()`, that does not (Heikki Linnakangas)

  This change affects no core code, but might prevent crashes in add-on code that expects `DatumGetInetP()` to produce an unpacked datum as per usual convention.
- Improve locale support in `money` type's input and output (Tom Lane)

  Aside from not supporting all standard `lc_monetary` formatting options, the input and output functions were inconsistent, meaning there were locales in which dumped `money` values could not be re-read.
- Don't let `transform_null_equals` affect `CASE foo WHEN NULL ...` constructs (Heikki Linnakangas)

  `transform_null_equals` is only supposed to affect `foo = NULL` expressions written directly by the user, not equality checks generated internally by this form of `CASE`.
- Change foreign-key trigger creation order to better support self-referential foreign keys (Tom Lane)

  For a cascading foreign key that references its own table, a row update will fire both the `ON UPDATE` trigger and the `CHECK` trigger as one event. The `ON UPDATE` trigger must execute first, else the `CHECK` will check a non-final state of the row and possibly throw an inappropriate error. However, the firing order of these triggers is determined by their names, which generally sort in creation order since the triggers have auto-generated names following the convention "RI_ConstraintTrigger_NNNN". A proper fix would require modifying that convention, which we will do in 9.2, but it seems risky to change it in existing releases. So this patch just changes the creation order of the triggers. Users encountering this type of error should drop and re-create the foreign key constraint to get its triggers into the right order.
- Avoid floating-point underflow while tracking buffer allocation rate (Greg Matthews)

  While harmless in itself, on certain platforms this would result in annoying kernel log messages.

- Preserve configuration file name and line number values when starting child processes under Windows (Tom Lane)

  Formerly, these would not be displayed correctly in the `pg_settings` view.

- Fix incorrect field alignment in ecpg's SQLDA area (Zoltan Boszormenyi)

- Preserve blank lines within commands in psql's command history (Robert Haas)

  The former behavior could cause problems if an empty line was removed from within a string literal, for example.

- Fix pg_dump to dump user-defined casts between auto-generated types, such as table rowtypes (Tom Lane)

- Assorted fixes for pg_upgrade (Bruce Momjian)

  Handle exclusion constraints correctly, avoid failures on Windows, don't complain about mismatched toast table names in 8.4 databases.

- Use the preferred version of xsubpp to build PL/Perl, not necessarily the operating system's main copy (David Wheeler and Alex Hunsaker)

- Fix incorrect coding in `contrib/dict_int` and `contrib/dict_xsyn` (Tom Lane)

  Some functions incorrectly assumed that memory returned by `palloc()` is guaranteed zeroed.

- Fix assorted errors in `contrib/unaccent`'s configuration file parsing (Tom Lane)

- Honor query cancel interrupts promptly in `pgstatindex()` (Robert Haas)

- Fix incorrect quoting of log file name in Mac OS X start script (Sidar Lopez)

- Ensure VPATH builds properly install all server header files (Peter Eisentraut)

- Shorten file names reported in verbose error messages (Peter Eisentraut)

  Regular builds have always reported just the name of the C file containing the error message call, but VPATH builds formerly reported an absolute path name.

- Fix interpretation of Windows timezone names for Central America (Tom Lane)

  Map "Central America Standard Time" to `CST6`, not `CST6CDT`, because DST is generally not observed anywhere in Central America.

- Update time zone data files to tzdata release 2011n for DST law changes in Brazil, Cuba, Fiji, Palestine, Russia, and Samoa; also historical corrections for Alaska and British East Africa.

E.51. Release 9.0.5

Release Date: 2011-09-26

This release contains a variety of fixes from 9.0.4. For information about new features in the 9.0 major release, see Section E.56.

E.51.1. Migration to Version 9.0.5

A dump/restore is not required for those running 9.0.X.

However, if you are upgrading from a version earlier than 9.0.4, see Section E.52.

E.51.2. Changes

- Fix catalog cache invalidation after a `VACUUM FULL` or `CLUSTER` on a system catalog (Tom Lane)

  In some cases the relocation of a system catalog row to another place would not be recognized by concurrent server processes, allowing catalog corruption to occur if they then tried to update that row. The worst-case outcome could be as bad as complete loss of a table.

- Fix incorrect order of operations during sinval reset processing, and ensure that TOAST OIDs are preserved in system catalogs (Tom Lane)

  These mistakes could lead to transient failures after a `VACUUM FULL` or `CLUSTER` on a system catalog.

- Fix bugs in indexing of in-doubt HOT-updated tuples (Tom Lane)

  These bugs could result in index corruption after reindexing a system catalog. They are not believed to affect user indexes.

- Fix multiple bugs in GiST index page split processing (Heikki Linnakangas)

  The probability of occurrence was low, but these could lead to index corruption.

- Fix possible buffer overrun in `tsvector_concat()` (Tom Lane)

  The function could underestimate the amount of memory needed for its result, leading to server crashes.

- Fix crash in `xml_recv` when processing a "standalone" parameter (Tom Lane)

- Make `pg_options_to_table` return NULL for an option with no value (Tom Lane)

  Previously such cases would result in a server crash.

- Avoid possibly accessing off the end of memory in `ANALYZE` and in SJIS-2004 encoding conversion (Noah Misch)

  This fixes some very-low-probability server crash scenarios.

- Protect `pg_stat_reset_shared()` against NULL input (Magnus Hagander)

- Fix possible failure when a recovery conflict deadlock is detected within a sub-transaction (Tom Lane)

- Avoid spurious conflicts while recycling btree index pages during hot standby (Noah Misch, Simon Riggs)

- Shut down WAL receiver if it's still running at end of recovery (Heikki Linnakangas)

  The postmaster formerly panicked in this situation, but it's actually a legitimate case.

- Fix race condition in relcache init file invalidation (Tom Lane)

  There was a window wherein a new backend process could read a stale init file but miss the inval messages that would tell it the data is stale. The result would be bizarre failures in catalog accesses, typically "could not read block 0 in file ..." later during startup.

- Fix memory leak at end of a GiST index scan (Tom Lane)

  Commands that perform many separate GiST index scans, such as verification of a new GiST-based exclusion constraint on a table already containing many rows, could transiently require large amounts of memory due to this leak.

- Fix memory leak when encoding conversion has to be done on incoming command strings and `LISTEN` is active (Tom Lane)
- Fix incorrect memory accounting (leading to possible memory bloat) in tuplestores supporting holdable cursors and plpgsql's `RETURN NEXT` command (Tom Lane)
- Fix trigger `WHEN` conditions when both `BEFORE` and `AFTER` triggers exist (Tom Lane)

  Evaluation of `WHEN` conditions for `AFTER ROW UPDATE` triggers could crash if there had been a `BEFORE ROW` trigger fired for the same update.
- Fix performance problem when constructing a large, lossy bitmap (Tom Lane)
- Fix join selectivity estimation for unique columns (Tom Lane)

  This fixes an erroneous planner heuristic that could lead to poor estimates of the result size of a join.
- Fix nested PlaceHolderVar expressions that appear only in sub-select target lists (Tom Lane)

  This mistake could result in outputs of an outer join incorrectly appearing as NULL.
- Allow the planner to assume that empty parent tables really are empty (Tom Lane)

  Normally an empty table is assumed to have a certain minimum size for planning purposes; but this heuristic seems to do more harm than good for the parent table of an inheritance hierarchy, which often is permanently empty.
- Allow nested `EXISTS` queries to be optimized properly (Tom Lane)
- Fix array- and path-creating functions to ensure padding bytes are zeroes (Tom Lane)

  This avoids some situations where the planner will think that semantically-equal constants are not equal, resulting in poor optimization.
- Fix `EXPLAIN` to handle gating Result nodes within inner-indexscan subplans (Tom Lane)

  The usual symptom of this oversight was "bogus varno" errors.
- Fix btree preprocessing of *`indexedcol`* `IS NULL` conditions (Dean Rasheed)

  Such a condition is unsatisfiable if combined with any other type of btree-indexable condition on the same index column. The case was handled incorrectly in 9.0.0 and later, leading to query output where there should be none.
- Work around gcc 4.6.0 bug that breaks WAL replay (Tom Lane)

  This could lead to loss of committed transactions after a server crash.
- Fix dump bug for `VALUES` in a view (Tom Lane)
- Disallow `SELECT FOR UPDATE/SHARE` on sequences (Tom Lane)

  This operation doesn't work as expected and can lead to failures.
- Fix `VACUUM` so that it always updates `pg_class.reltuples`/`relpages` (Tom Lane)

  This fixes some scenarios where autovacuum could make increasingly poor decisions about when to vacuum tables.
- Defend against integer overflow when computing size of a hash table (Tom Lane)
- Fix cases where `CLUSTER` might attempt to access already-removed TOAST data (Tom Lane)
- Fix premature timeout failures during initial authentication transaction (Tom Lane)
- Fix portability bugs in use of credentials control messages for "peer" authentication (Tom Lane)
- Fix SSPI login when multiple roundtrips are required (Ahmed Shinwari, Magnus Hagander)

The typical symptom of this problem was "The function requested is not supported" errors during SSPI login.

- Fix failure when adding a new variable of a custom variable class to `postgresql.conf` (Tom Lane)
- Throw an error if `pg_hba.conf` contains `hostssl` but SSL is disabled (Tom Lane)

  This was concluded to be more user-friendly than the previous behavior of silently ignoring such lines.
- Fix failure when `DROP OWNED BY` attempts to remove default privileges on sequences (Shigeru Hanada)
- Fix typo in `pg_srand48` seed initialization (Andres Freund)

  This led to failure to use all bits of the provided seed. This function is not used on most platforms (only those without `srandom`), and the potential security exposure from a less-random-than-expected seed seems minimal in any case.
- Avoid integer overflow when the sum of `LIMIT` and `OFFSET` values exceeds 2^63 (Heikki Linnakangas)
- Add overflow checks to `int4` and `int8` versions of `generate_series()` (Robert Haas)
- Fix trailing-zero removal in `to_char()` (Marti Raudsepp)

  In a format with `FM` and no digit positions after the decimal point, zeroes to the left of the decimal point could be removed incorrectly.
- Fix `pg_size_pretty()` to avoid overflow for inputs close to 2^63 (Tom Lane)
- Weaken plpgsql's check for typmod matching in record values (Tom Lane)

  An overly enthusiastic check could lead to discarding length modifiers that should have been kept.
- Correctly handle quotes in locale names during initdb (Heikki Linnakangas)

  The case can arise with some Windows locales, such as "People's Republic of China".
- In pg_upgrade, avoid dumping orphaned temporary tables (Bruce Momjian)

  This prevents situations wherein table OID assignments could get out of sync between old and new installations.
- Fix pg_upgrade to preserve toast tables' relfrozenxids during an upgrade from 8.3 (Bruce Momjian)

  Failure to do this could lead to `pg_clog` files being removed too soon after the upgrade.
- In pg_upgrade, fix the `-l` (log) option to work on Windows (Bruce Momjian)
- In pg_ctl, support silent mode for service registrations on Windows (MauMau)
- Fix psql's counting of script file line numbers during `COPY` from a different file (Tom Lane)
- Fix pg_restore's direct-to-database mode for `standard_conforming_strings` (Tom Lane)

  pg_restore could emit incorrect commands when restoring directly to a database server from an archive file that had been made with `standard_conforming_strings` set to `on`.
- Be more user-friendly about unsupported cases for parallel pg_restore (Tom Lane)

  This change ensures that such cases are detected and reported before any restore actions have been taken.
- Fix write-past-buffer-end and memory leak in libpq's LDAP service lookup code (Albe Laurenz)
- In libpq, avoid failures when using nonblocking I/O and an SSL connection (Martin Pihlak, Tom Lane)

- Improve libpq's handling of failures during connection startup (Tom Lane)

  In particular, the response to a server report of `fork()` failure during SSL connection startup is now saner.

- Improve libpq's error reporting for SSL failures (Tom Lane)
- Fix `PQsetvalue()` to avoid possible crash when adding a new tuple to a `PGresult` originally obtained from a server query (Andrew Chernow)
- Make ecpglib write `double` values with 15 digits precision (Akira Kurosawa)
- In ecpglib, be sure `LC_NUMERIC` setting is restored after an error (Michael Meskes)
- Apply upstream fix for blowfish signed-character bug (CVE-2011-2483) (Tom Lane)

  `contrib/pg_crypto`'s blowfish encryption code could give wrong results on platforms where char is signed (which is most), leading to encrypted passwords being weaker than they should be.

- Fix memory leak in `contrib/seg` (Heikki Linnakangas)
- Fix `pgstatindex()` to give consistent results for empty indexes (Tom Lane)
- Allow building with perl 5.14 (Alex Hunsaker)
- Fix assorted issues with build and install file paths containing spaces (Tom Lane)
- Update time zone data files to tzdata release 2011i for DST law changes in Canada, Egypt, Russia, Samoa, and South Sudan.

E.52. Release 9.0.4

Release Date: 2011-04-18

This release contains a variety of fixes from 9.0.3. For information about new features in the 9.0 major release, see Section E.56.

E.52.1. Migration to Version 9.0.4

A dump/restore is not required for those running 9.0.X.

However, if your installation was upgraded from a previous major release by running pg_upgrade, you should take action to prevent possible data loss due to a now-fixed bug in pg_upgrade. The recommended solution is to run `VACUUM FREEZE` on all TOAST tables. More information is available at http://wiki.postgresql.org/wiki/20110408pg_upgrade_fix[3].

E.52.2. Changes

- Fix pg_upgrade's handling of TOAST tables (Bruce Momjian)

  The `pg_class.relfrozenxid` value for TOAST tables was not correctly copied into the new installation during pg_upgrade. This could later result in `pg_clog` files being discarded while they

3. http://wiki.postgresql.org/wiki/20110408pg_upgrade_fix

were still needed to validate tuples in the TOAST tables, leading to "could not access status of transaction" failures.

This error poses a significant risk of data loss for installations that have been upgraded with pg_upgrade. This patch corrects the problem for future uses of pg_upgrade, but does not in itself cure the issue in installations that have been processed with a buggy version of pg_upgrade.

- Suppress incorrect "PD_ALL_VISIBLE flag was incorrectly set" warning (Heikki Linnakangas)

  `VACUUM` would sometimes issue this warning in cases that are actually valid.

- Use better SQLSTATE error codes for hot standby conflict cases (Tatsuo Ishii and Simon Riggs)

  All retryable conflict errors now have an error code that indicates that a retry is possible. Also, session closure due to the database being dropped on the master is now reported as `ERRCODE_DATABASE_DROPPED`, rather than `ERRCODE_ADMIN_SHUTDOWN`, so that connection poolers can handle the situation correctly.

- Prevent intermittent hang in interactions of startup process with bgwriter process (Simon Riggs)

  This affected recovery in non-hot-standby cases.

- Disallow including a composite type in itself (Tom Lane)

  This prevents scenarios wherein the server could recurse infinitely while processing the composite type. While there are some possible uses for such a structure, they don't seem compelling enough to justify the effort required to make sure it always works safely.

- Avoid potential deadlock during catalog cache initialization (Nikhil Sontakke)

  In some cases the cache loading code would acquire share lock on a system index before locking the index's catalog. This could deadlock against processes trying to acquire exclusive locks in the other, more standard order.

- Fix dangling-pointer problem in `BEFORE ROW UPDATE` trigger handling when there was a concurrent update to the target tuple (Tom Lane)

  This bug has been observed to result in intermittent "cannot extract system attribute from virtual tuple" failures while trying to do `UPDATE RETURNING ctid`. There is a very small probability of more serious errors, such as generating incorrect index entries for the updated tuple.

- Disallow `DROP TABLE` when there are pending deferred trigger events for the table (Tom Lane)

  Formerly the `DROP` would go through, leading to "could not open relation with OID nnn" errors when the triggers were eventually fired.

- Allow "replication" as a user name in `pg_hba.conf` (Andrew Dunstan)

  "replication" is special in the database name column, but it was mistakenly also treated as special in the user name column.

- Prevent crash triggered by constant-false WHERE conditions during GEQO optimization (Tom Lane)

- Improve planner's handling of semi-join and anti-join cases (Tom Lane)

- Fix handling of `SELECT FOR UPDATE` in a sub-SELECT (Tom Lane)

  This bug typically led to "cannot extract system attribute from virtual tuple" errors.

- Fix selectivity estimation for text search to account for NULLs (Jesper Krogh)

- Fix get_actual_variable_range() to support hypothetical indexes injected by an index adviser plugin (Gurjeet Singh)

- Fix PL/Python memory leak involving array slices (Daniel Popowich)

- Allow libpq's SSL initialization to succeed when user's home directory is unavailable (Tom Lane)

  If the SSL mode is such that a root certificate file is not required, there is no need to fail. This change restores the behavior to what it was in pre-9.0 releases.

- Fix libpq to return a useful error message for errors detected in `conninfo_array_parse` (Joseph Adams)

  A typo caused the library to return NULL, rather than the `PGconn` structure containing the error message, to the application.

- Fix ecpg preprocessor's handling of float constants (Heikki Linnakangas)
- Fix parallel pg_restore to handle comments on POST_DATA items correctly (Arnd Hannemann)
- Fix pg_restore to cope with long lines (over 1KB) in TOC files (Tom Lane)
- Put in more safeguards against crashing due to division-by-zero with overly enthusiastic compiler optimization (Aurelien Jarno)
- Support use of dlopen() in FreeBSD and OpenBSD on MIPS (Tom Lane)

  There was a hard-wired assumption that this system function was not available on MIPS hardware on these systems. Use a compile-time test instead, since more recent versions have it.

- Fix compilation failures on HP-UX (Heikki Linnakangas)
- Avoid crash when trying to write to the Windows console very early in process startup (Rushabh Lathia)
- Support building with MinGW 64 bit compiler for Windows (Andrew Dunstan)
- Fix version-incompatibility problem with libintl on Windows (Hiroshi Inoue)
- Fix usage of xcopy in Windows build scripts to work correctly under Windows 7 (Andrew Dunstan)

  This affects the build scripts only, not installation or usage.

- Fix path separator used by pg_regress on Cygwin (Andrew Dunstan)
- Update time zone data files to tzdata release 2011f for DST law changes in Chile, Cuba, Falkland Islands, Morocco, Samoa, and Turkey; also historical corrections for South Australia, Alaska, and Hawaii.

E.53. Release 9.0.3

Release Date: 2011-01-31

This release contains a variety of fixes from 9.0.2. For information about new features in the 9.0 major release, see Section E.56.

E.53.1. Migration to Version 9.0.3

A dump/restore is not required for those running 9.0.X.

E.53.2. Changes

- Before exiting walreceiver, ensure all the received WAL is fsync'd to disk (Heikki Linnakangas)

  Otherwise the standby server could replay some un-synced WAL, conceivably leading to data corruption if the system crashes just at that point.

- Avoid excess fsync activity in walreceiver (Heikki Linnakangas)

- Make `ALTER TABLE` revalidate uniqueness and exclusion constraints when needed (Noah Misch)

  This was broken in 9.0 by a change that was intended to suppress revalidation during `VACUUM FULL` and `CLUSTER`, but unintentionally affected `ALTER TABLE` as well.

- Fix EvalPlanQual for `UPDATE` of an inheritance tree in which the tables are not all alike (Tom Lane)

  Any variation in the table row types (including dropped columns present in only some child tables) would confuse the EvalPlanQual code, leading to misbehavior or even crashes. Since EvalPlanQual is only executed during concurrent updates to the same row, the problem was only seen intermittently.

- Avoid failures when `EXPLAIN` tries to display a simple-form `CASE` expression (Tom Lane)

  If the `CASE`'s test expression was a constant, the planner could simplify the `CASE` into a form that confused the expression-display code, resulting in "unexpected CASE WHEN clause" errors.

- Fix assignment to an array slice that is before the existing range of subscripts (Tom Lane)

  If there was a gap between the newly added subscripts and the first pre-existing subscript, the code miscalculated how many entries needed to be copied from the old array's null bitmap, potentially leading to data corruption or crash.

- Avoid unexpected conversion overflow in planner for very distant date values (Tom Lane)

  The `date` type supports a wider range of dates than can be represented by the `timestamp` types, but the planner assumed it could always convert a date to timestamp with impunity.

- Fix PL/Python crash when an array contains null entries (Alex Hunsaker)

- Remove ecpg's fixed length limit for constants defining an array dimension (Michael Meskes)

- Fix erroneous parsing of `tsquery` values containing `... & !(subexpression) | ...` (Tom Lane)

  Queries containing this combination of operators were not executed correctly. The same error existed in `contrib/intarray`'s `query_int` type and `contrib/ltree`'s `ltxtquery` type.

- Fix buffer overrun in `contrib/intarray`'s input function for the `query_int` type (Apple)

  This bug is a security risk since the function's return address could be overwritten. Thanks to Apple Inc's security team for reporting this issue and supplying the fix. (CVE-2010-4015)

- Fix bug in `contrib/seg`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `seg` column. If you have such an index, consider `REINDEX`ing it after installing this update. (This is identical to the bug that was fixed in `contrib/cube` in the previous update.)

E.54. Release 9.0.2

Release Date: 2010-12-16

This release contains a variety of fixes from 9.0.1. For information about new features in the 9.0 major release, see Section E.56.

E.54.1. Migration to Version 9.0.2

A dump/restore is not required for those running 9.0.X.

E.54.2. Changes

- Force the default `wal_sync_method` to be `fdatasync` on Linux (Tom Lane, Marti Raudsepp)

  The default on Linux has actually been `fdatasync` for many years, but recent kernel changes caused PostgreSQL to choose `open_datasync` instead. This choice did not result in any performance improvement, and caused outright failures on certain filesystems, notably `ext4` with the `data=journal` mount option.
- Fix "too many KnownAssignedXids" error during Hot Standby replay (Heikki Linnakangas)
- Fix race condition in lock acquisition during Hot Standby (Simon Riggs)
- Avoid unnecessary conflicts during Hot Standby (Simon Riggs)

  This fixes some cases where replay was considered to conflict with standby queries (causing delay of replay or possibly cancellation of the queries), but there was no real conflict.
- Fix assorted bugs in WAL replay logic for GIN indexes (Tom Lane)

  This could result in "bad buffer id: 0" failures or corruption of index contents during replication.
- Fix recovery from base backup when the starting checkpoint WAL record is not in the same WAL segment as its redo point (Jeff Davis)
- Fix corner-case bug when streaming replication is enabled immediately after creating the master database cluster (Heikki Linnakangas)
- Fix persistent slowdown of autovacuum workers when multiple workers remain active for a long time (Tom Lane)

  The effective `vacuum_cost_limit` for an autovacuum worker could drop to nearly zero if it processed enough tables, causing it to run extremely slowly.
- Fix long-term memory leak in autovacuum launcher (Alvaro Herrera)
- Avoid failure when trying to report an impending transaction wraparound condition from outside a transaction (Tom Lane)

  This oversight prevented recovery after transaction wraparound got too close, because database startup processing would fail.
- Add support for detecting register-stack overrun on `IA64` (Tom Lane)

  The `IA64` architecture has two hardware stacks. Full prevention of stack-overrun failures requires checking both.

- Add a check for stack overflow in `copyObject()` (Tom Lane)

  Certain code paths could crash due to stack overflow given a sufficiently complex query.

- Fix detection of page splits in temporary GiST indexes (Heikki Linnakangas)

  It is possible to have a "concurrent" page split in a temporary index, if for example there is an open cursor scanning the index when an insertion is done. GiST failed to detect this case and hence could deliver wrong results when execution of the cursor continued.

- Fix error checking during early connection processing (Tom Lane)

  The check for too many child processes was skipped in some cases, possibly leading to postmaster crash when attempting to add the new child process to fixed-size arrays.

- Improve efficiency of window functions (Tom Lane)

  Certain cases where a large number of tuples needed to be read in advance, but `work_mem` was large enough to allow them all to be held in memory, were unexpectedly slow. `percent_rank()`, `cume_dist()` and `ntile()` in particular were subject to this problem.

- Avoid memory leakage while `ANALYZE`'ing complex index expressions (Tom Lane)

- Ensure an index that uses a whole-row Var still depends on its table (Tom Lane)

  An index declared like `create index i on t (foo(t.*))` would not automatically get dropped when its table was dropped.

- Add missing support in `DROP OWNED BY` for removing foreign data wrapper/server privileges belonging to a user (Heikki Linnakangas)

- Do not "inline" a SQL function with multiple `OUT` parameters (Tom Lane)

  This avoids a possible crash due to loss of information about the expected result rowtype.

- Fix crash when inline-ing a set-returning function whose argument list contains a reference to an inline-able user function (Tom Lane)

- Behave correctly if `ORDER BY`, `LIMIT`, `FOR UPDATE`, or `WITH` is attached to the `VALUES` part of `INSERT ... VALUES` (Tom Lane)

- Make the `OFF` keyword unreserved (Heikki Linnakangas)

  This prevents problems with using `off` as a variable name in PL/pgSQL. That worked before 9.0, but was now broken because PL/pgSQL now treats all core reserved words as reserved.

- Fix constant-folding of `COALESCE()` expressions (Tom Lane)

  The planner would sometimes attempt to evaluate sub-expressions that in fact could never be reached, possibly leading to unexpected errors.

- Fix "could not find pathkey item to sort" planner failure with comparison of whole-row Vars (Tom Lane)

- Fix postmaster crash when connection acceptance (`accept()` or one of the calls made immediately after it) fails, and the postmaster was compiled with GSSAPI support (Alexander Chernikov)

- Retry after receiving an invalid response packet from a RADIUS authentication server (Magnus Hagander)

  This fixes a low-risk potential denial of service condition.

- Fix missed unlink of temporary files when `log_temp_files` is active (Tom Lane)

  If an error occurred while attempting to emit the log message, the unlink was not done, resulting in accumulation of temp files.

- Add print functionality for `InhRelation` nodes (Tom Lane)

This avoids a failure when `debug_print_parse` is enabled and certain types of query are executed.

- Fix incorrect calculation of distance from a point to a horizontal line segment (Tom Lane)

  This bug affected several different geometric distance-measurement operators.

- Fix incorrect calculation of transaction status in ecpg (Itagaki Takahiro)
- Fix errors in psql's Unicode-escape support (Tom Lane)
- Speed up parallel pg_restore when the archive contains many large objects (blobs) (Tom Lane)
- Fix PL/pgSQL's handling of "simple" expressions to not fail in recursion or error-recovery cases (Tom Lane)
- Fix PL/pgSQL's error reporting for no-such-column cases (Tom Lane)

  As of 9.0, it would sometimes report "missing FROM-clause entry for table foo" when "record foo has no field bar" would be more appropriate.

- Fix PL/Python to honor typmod (i.e., length or precision restrictions) when assigning to tuple fields (Tom Lane)

  This fixes a regression from 8.4.

- Fix PL/Python's handling of set-returning functions (Jan Urbanski)

  Attempts to call SPI functions within the iterator generating a set result would fail.

- Fix bug in `contrib/cube`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `cube` column. If you have such an index, consider `REINDEX`ing it after installing this update.

- Don't emit "identifier will be truncated" notices in `contrib/dblink` except when creating new connections (Itagaki Takahiro)
- Fix potential coredump on missing public key in `contrib/pgcrypto` (Marti Raudsepp)
- Fix buffer overrun in `contrib/pg_upgrade` (Hernan Gonzalez)
- Fix memory leak in `contrib/xml2`'s XPath query functions (Tom Lane)
- Update time zone data files to tzdata release 2010o for DST law changes in Fiji and Samoa; also historical corrections for Hong Kong.

E.55. Release 9.0.1

Release Date: 2010-10-04

This release contains a variety of fixes from 9.0.0. For information about new features in the 9.0 major release, see Section E.56.

E.55.1. Migration to Version 9.0.1

A dump/restore is not required for those running 9.0.X.

E.55.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

  It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

  Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Improve `pg_get_expr()` security fix so that the function can still be used on the output of a sub-select (Tom Lane)
- Fix incorrect placement of placeholder evaluation (Tom Lane)

  This bug could result in query outputs being non-null when they should be null, in cases where the inner side of an outer join is a sub-select with non-strict expressions in its output list.

- Fix join removal's handling of placeholder expressions (Tom Lane)
- Fix possible duplicate scans of `UNION ALL` member relations (Tom Lane)
- Prevent infinite loop in ProcessIncomingNotify() after unlistening (Jeff Davis)
- Prevent show_session_authorization() from crashing within autovacuum processes (Tom Lane)
- Re-allow input of Julian dates prior to 0001-01-01 AD (Tom Lane)

  Input such as `'J100000'::date` worked before 8.4, but was unintentionally broken by added error-checking.

- Make psql recognize `DISCARD ALL` as a command that should not be encased in a transaction block in autocommit-off mode (Itagaki Takahiro)
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)

E.56. Release 9.0

Release Date: 2010-09-20

E.56.1. Overview

This release of PostgreSQL adds features that have been requested for years, such as easy-to-use replication, a mass permission-changing facility, and anonymous code blocks. While past major releases have been conservative in their scope, this release shows a bold new desire to provide facilities that new and existing users of PostgreSQL will embrace. This has all been done with few incompatibilities. Major enhancements include:

- Built-in replication based on log shipping. This advance consists of two features: Streaming Replication, allowing continuous archive (WAL) files to be streamed over a network connection to a standby server, and Hot Standby, allowing continuous archive standby servers to execute read-only queries. The net effect is to support a single master with multiple read-only slave servers.
- Easier database object permissions management. `GRANT`/`REVOKE IN SCHEMA` supports mass permissions changes on existing objects, while `ALTER DEFAULT PRIVILEGES` allows control of privileges for objects created in the future. Large objects (BLOBs) now support permissions management as well.
- Broadly enhanced stored procedure support. The `DO` statement supports ad-hoc or "anonymous" code blocks. Functions can now be called using named parameters. PL/pgSQL is now installed by default, and PL/Perl and PL/Python have been enhanced in several ways, including support for Python3.
- Full support for 64-bit Windows.
- More advanced reporting queries, including additional windowing options (`PRECEDING` and `FOLLOWING`) and the ability to control the order in which values are fed to aggregate functions.
- New trigger features, including SQL-standard-compliant per-column triggers and conditional trigger execution.
- Deferrable unique constraints. Mass updates to unique keys are now possible without trickery.
- Exclusion constraints. These provide a generalized version of unique constraints, allowing enforcement of complex conditions.
- New and enhanced security features, including RADIUS authentication, LDAP authentication improvements, and a new contrib module `passwordcheck` for testing password strength.
- New high-performance implementation of the `LISTEN`/`NOTIFY` feature. Pending events are now stored in a memory-based queue rather than a table. Also, a "payload" string can be sent with each event, rather than transmitting just an event name as before.
- New implementation of `VACUUM FULL`. This command now rewrites the entire table and indexes, rather than moving individual rows to compact space. It is substantially faster in most cases, and no longer results in index bloat.
- New contrib module `pg_upgrade` to support in-place upgrades from 8.3 or 8.4 to 9.0.
- Multiple performance enhancements for specific types of queries, including elimination of unnecessary joins. This helps optimize some automatically-generated queries, such as those produced by object-relational mappers (ORMs).
- `EXPLAIN` enhancements. The output is now available in JSON, XML, or YAML format, and includes buffer utilization and other data not previously available.
- `hstore` improvements, including new functions and greater data capacity.

The above items are explained in more detail in the sections below.

E.56.2. Migration to Version 9.0

A dump/restore using pg_dump, or use of pg_upgrade, is required for those wishing to migrate data from any previous release.

Version 9.0 contains a number of changes that selectively break backwards compatibility in order to support new features and code quality improvements. In particular, users who make extensive use of PL/pgSQL, Point-In-Time Recovery (PITR), or Warm Standby should test their applications because of slight user-visible changes in those areas. Observe the following incompatibilities:

E.56.2.1. Server Settings

- Remove server parameter `add_missing_from`, which was defaulted to off for many years (Tom Lane)
- Remove server parameter `regex_flavor`, which was defaulted to `advanced` for many years (Tom Lane)
- `archive_mode` now only affects `archive_command`; a new setting, `wal_level`, affects the contents of the write-ahead log (Heikki Linnakangas)
- `log_temp_files` now uses default file size units of kilobytes (Robert Haas)

E.56.2.2. Queries

- When querying a parent table, do not do any separate permission checks on child tables scanned as part of the query (Peter Eisentraut)

  The SQL standard specifies this behavior, and it is also much more convenient in practice than the former behavior of checking permissions on each child as well as the parent.

E.56.2.3. Data Types

- `bytea` output now appears in hex format by default (Peter Eisentraut)

  The server parameter `bytea_output` can be used to select the traditional output format if needed for compatibility.
- Array input now considers only plain ASCII whitespace characters to be potentially ignorable; it will never ignore non-ASCII characters, even if they are whitespace according to some locales (Tom Lane)

  This avoids some corner cases where array values could be interpreted differently depending on the server's locale settings.
- Improve standards compliance of `SIMILAR TO` patterns and SQL-style `substring()` patterns (Tom Lane)

  This includes treating `?` and `{...}` as pattern metacharacters, while they were simple literal characters before; that corresponds to new features added in SQL:2008. Also, `^` and `$` are now treated as simple literal characters; formerly they were treated as metacharacters, as if the pattern were following POSIX rather than SQL rules. Also, in SQL-standard `substring()`, use of parentheses for nesting no longer interferes with capturing of a substring. Also, processing of bracket expressions (character classes) is now more standards-compliant.

- Reject negative length values in 3-parameter `substring()` for bit strings, per the SQL standard (Tom Lane)
- Make `date_trunc` truncate rather than round when reducing precision of fractional seconds (Tom Lane)

  The code always acted this way for integer-based dates/times. Now float-based dates/times behave similarly.

E.56.2.4. Object Renaming

- Tighten enforcement of column name consistency during `RENAME` when a child table inherits the same column from multiple unrelated parents (KaiGai Kohei)
- No longer automatically rename indexes and index columns when the underlying table columns are renamed (Tom Lane)

  Administrators can still rename such indexes and columns manually. This change will require an update of the JDBC driver, and possibly other drivers, so that unique indexes are correctly recognized after a rename.
- `CREATE OR REPLACE FUNCTION` can no longer change the declared names of function parameters (Pavel Stehule)

  In order to avoid creating ambiguity in named-parameter calls, it is no longer allowed to change the aliases for input parameters in the declaration of an existing function (although names can still be assigned to previously unnamed parameters). You now have to `DROP` and recreate the function to do that.

E.56.2.5. PL/pgSQL

- PL/pgSQL now throws an error if a variable name conflicts with a column name used in a query (Tom Lane)

  The former behavior was to bind ambiguous names to PL/pgSQL variables in preference to query columns, which often resulted in surprising misbehavior. Throwing an error allows easy detection of ambiguous situations. Although it's recommended that functions encountering this type of error be modified to remove the conflict, the old behavior can be restored if necessary via the configuration parameter `plpgsql.variable_conflict`, or via the per-function option `#variable_conflict`.
- PL/pgSQL no longer allows variable names that match certain SQL reserved words (Tom Lane)

  This is a consequence of aligning the PL/pgSQL parser to match the core SQL parser more closely. If necessary, variable names can be double-quoted to avoid this restriction.
- PL/pgSQL now requires columns of composite results to match the expected type modifier as well as base type (Pavel Stehule, Tom Lane)

  For example, if a column of the result type is declared as `NUMERIC(30,2)`, it is no longer acceptable to return a `NUMERIC` of some other precision in that column. Previous versions neglected to check the type modifier and would thus allow result rows that didn't actually conform to the declared restrictions.
- PL/pgSQL now treats selection into composite fields more consistently (Tom Lane)

Formerly, a statement like `SELECT ... INTO rec.fld FROM ...` was treated as a scalar assignment even if the record field *fld* was of composite type. Now it is treated as a record assignment, the same as when the `INTO` target is a regular variable of composite type. So the values to be assigned to the field's subfields should be written as separate columns of the `SELECT` list, not as a `ROW(...)` construct as in previous versions.

If you need to do this in a way that will work in both 9.0 and previous releases, you can write something like `rec.fld := ROW(...) FROM ...`.

- Remove PL/pgSQL's `RENAME` declaration (Tom Lane)

  Instead of `RENAME`, use `ALIAS`, which can now create an alias for any variable, not only dollar sign parameter names (such as `$1`) as before.

E.56.2.6. Other Incompatibilities

- Deprecate use of => as an operator name (Robert Haas)

  Future versions of PostgreSQL will probably reject this operator name entirely, in order to support the SQL-standard notation for named function parameters. For the moment, it is still allowed, but a warning is emitted when such an operator is defined.

- Remove support for platforms that don't have a working 64-bit integer data type (Tom Lane)

  It is believed all still-supported platforms have working 64-bit integer data types.

E.56.3. Changes

Version 9.0 has an unprecedented number of new major features, and over 200 enhancements, improvements, new commands, new functions, and other changes.

E.56.3.1. Server

E.56.3.1.1. Continuous Archiving and Streaming Replication

PostgreSQL's existing standby-server capability has been expanded both to support read-only queries on standby servers and to greatly reduce the lag between master and standby servers. For many users, this will be a useful and low-administration form of replication, either for high availability or for horizontal scalability.

- Allow a standby server to accept read-only queries (Simon Riggs, Heikki Linnakangas)

  This feature is called Hot Standby. There are new `postgresql.conf` and `recovery.conf` settings to control this feature, as well as extensive documentation.

- Allow write-ahead log (WAL) data to be streamed to a standby server (Fujii Masao, Heikki Linnakangas)

  This feature is called Streaming Replication. Previously WAL data could be sent to standby servers only in units of entire WAL files (normally 16 megabytes each). Streaming Replication eliminates this inefficiency and allows updates on the master to be propagated to standby servers with very little delay. There are new `postgresql.conf` and `recovery.conf` settings to control this feature, as well as extensive documentation.

- Add `pg_last_xlog_receive_location()` and `pg_last_xlog_replay_location()`, which can be used to monitor standby server WAL activity (Simon Riggs, Fujii Masao, Heikki Linnakangas)

E.56.3.1.2. Performance

- Allow per-tablespace values to be set for sequential and random page cost estimates (`seq_page_cost`/`random_page_cost`) via `ALTER TABLESPACE ... SET/RESET` (Robert Haas)
- Improve performance and reliability of EvalPlanQual rechecks in join queries (Tom Lane)

  `UPDATE`, `DELETE`, and `SELECT FOR UPDATE/SHARE` queries that involve joins will now behave much better when encountering freshly-updated rows.
- Improve performance of `TRUNCATE` when the table was created or truncated earlier in the same transaction (Tom Lane)
- Improve performance of finding inheritance child tables (Tom Lane)

E.56.3.1.3. Optimizer

- Remove unnecessary outer joins (Robert Haas)

  Outer joins where the inner side is unique and not referenced above the join are unnecessary and are therefore now removed. This will accelerate many automatically generated queries, such as those created by object-relational mappers (ORMs).
- Allow `IS NOT NULL` restrictions to use indexes (Tom Lane)

  This is particularly useful for finding `MAX()`/`MIN()` values in indexes that contain many null values.
- Improve the optimizer's choices about when to use materialize nodes, and when to use sorting versus hashing for `DISTINCT` (Tom Lane)
- Improve the optimizer's equivalence detection for expressions involving `boolean` <> operators (Tom Lane)

E.56.3.1.4. GEQO

- Use the same random seed every time GEQO plans a query (Andres Freund)

  While the Genetic Query Optimizer (GEQO) still selects random plans, it now always selects the same random plans for identical queries, thus giving more consistent performance. You can modify `geqo_seed` to experiment with alternative plans.
- Improve GEQO plan selection (Tom Lane)

  This avoids the rare error "failed to make a valid plan", and should also improve planning speed.

E.56.3.1.5. Optimizer Statistics

- Improve `ANALYZE` to support inheritance-tree statistics (Tom Lane)

This is particularly useful for partitioned tables. However, autovacuum does not yet automatically re-analyze parent tables when child tables change.

- Improve autovacuum's detection of when re-analyze is necessary (Tom Lane)
- Improve optimizer's estimation for greater/less-than comparisons (Tom Lane)

  When looking up statistics for greater/less-than comparisons, if the comparison value is in the first or last histogram bucket, use an index (if available) to fetch the current actual column minimum or maximum. This greatly improves the accuracy of estimates for comparison values near the ends of the data range, particularly if the range is constantly changing due to addition of new data.
- Allow setting of number-of-distinct-values statistics using `ALTER TABLE` (Robert Haas)

  This allows users to override the estimated number or percentage of distinct values for a column. This statistic is normally computed by `ANALYZE`, but the estimate can be poor, especially on tables with very large numbers of rows.

E.56.3.1.6. Authentication

- Add support for RADIUS (Remote Authentication Dial In User Service) authentication (Magnus Hagander)
- Allow LDAP (Lightweight Directory Access Protocol) authentication to operate in "search/bind" mode (Robert Fleming, Magnus Hagander)

  This allows the user to be looked up first, then the system uses the DN (Distinguished Name) returned for that user.
- Add `samehost` and `samenet` designations to `pg_hba.conf` (Stef Walter)

  These match the server's IP address and subnet address respectively.
- Pass trusted SSL root certificate names to the client so the client can return an appropriate client certificate (Craig Ringer)

E.56.3.1.7. Monitoring

- Add the ability for clients to set an application name, which is displayed in `pg_stat_activity` (Dave Page)

  This allows administrators to characterize database traffic and troubleshoot problems by source application.
- Add a SQLSTATE option (`%e`) to `log_line_prefix` (Guillaume Smet)

  This allows users to compile statistics on errors and messages by error code number.
- Write to the Windows event log in UTF16 encoding (Itagaki Takahiro)

  Now there is true multilingual support for PostgreSQL log messages on Windows.

E.56.3.1.8. Statistics Counters

- Add `pg_stat_reset_shared('bgwriter')` to reset the cluster-wide shared statistics for the background writer (Greg Smith)

- Add `pg_stat_reset_single_table_counters()` and `pg_stat_reset_single_function_counters()` to allow resetting the statistics counters for individual tables and functions (Magnus Hagander)

E.56.3.1.9. Server Settings

- Allow setting of configuration parameters based on database/role combinations (Alvaro Herrera)

  Previously only per-database and per-role settings were possible, not combinations. All role and database settings are now stored in the new `pg_db_role_setting` system catalog. A new psql command `\drds` shows these settings. The legacy system views `pg_roles`, `pg_shadow`, and `pg_user` do not show combination settings, and therefore no longer completely represent the configuration for a user or database.

- Add server parameter `bonjour`, which controls whether a Bonjour-enabled server advertises itself via Bonjour (Tom Lane)

  The default is off, meaning it does not advertise. This allows packagers to distribute Bonjour-enabled builds without worrying that individual users might not want the feature.

- Add server parameter `enable_material`, which controls the use of materialize nodes in the optimizer (Robert Haas)

  The default is on. When off, the optimizer will not add materialize nodes purely for performance reasons, though they will still be used when necessary for correctness.

- Change server parameter `log_temp_files` to use default file size units of kilobytes (Robert Haas)

  Previously this setting was interpreted in bytes if no units were specified.

- Log changes of parameter values when `postgresql.conf` is reloaded (Peter Eisentraut)

  This lets administrators and security staff audit changes of database settings, and is also very convenient for checking the effects of `postgresql.conf` edits.

- Properly enforce superuser permissions for custom server parameters (Tom Lane)

  Non-superusers can no longer issue `ALTER ROLE`/`DATABASE SET` for parameters that are not currently known to the server. This allows the server to correctly check that superuser-only parameters are only set by superusers. Previously, the `SET` would be allowed and then ignored at session start, making superuser-only custom parameters much less useful than they should be.

E.56.3.2. Queries

- Perform `SELECT FOR UPDATE`/`SHARE` processing after applying `LIMIT`, so the number of rows returned is always predictable (Tom Lane)

  Previously, changes made by concurrent transactions could cause a `SELECT FOR UPDATE` to unexpectedly return fewer rows than specified by its `LIMIT`. `FOR UPDATE` in combination with `ORDER BY` can still produce surprising results, but that can be corrected by placing `FOR UPDATE` in a subquery.

- Allow mixing of traditional and SQL-standard `LIMIT`/`OFFSET` syntax (Tom Lane)

- Extend the supported frame options in window functions (Hitoshi Harada)

Frames can now start with CURRENT ROW, and the ROWS *n* PRECEDING/FOLLOWING options are now supported.

- Make SELECT INTO and CREATE TABLE AS return row counts to the client in their command tags (Boszormenyi Zoltan)

  This can save an entire round-trip to the client, allowing result counts and pagination to be calculated without an additional COUNT query.

E.56.3.2.1. Unicode Strings

- Support Unicode surrogate pairs (dual 16-bit representation) in U& strings and identifiers (Peter Eisentraut)
- Support Unicode escapes in E'...' strings (Marko Kreen)

E.56.3.3. Object Manipulation

- Speed up CREATE DATABASE by deferring flushes to disk (Andres Freund, Greg Stark)
- Allow comments on columns of tables, views, and composite types only, not other relation types such as indexes and TOAST tables (Tom Lane)
- Allow the creation of enumerated types containing no values (Bruce Momjian)
- Let values of columns having storage type MAIN remain on the main heap page unless the row cannot fit on a page (Kevin Grittner)

  Previously MAIN values were forced out to TOAST tables until the row size was less than one-quarter of the page size.

E.56.3.3.1. ALTER TABLE

- Implement IF EXISTS for ALTER TABLE DROP COLUMN and ALTER TABLE DROP CONSTRAINT (Andres Freund)
- Allow ALTER TABLE commands that rewrite tables to skip WAL logging (Itagaki Takahiro)

  Such operations either produce a new copy of the table or are rolled back, so WAL archiving can be skipped, unless running in continuous archiving mode. This reduces I/O overhead and improves performance.
- Fix failure of ALTER TABLE *table* ADD COLUMN *col* serial when done by non-owner of table (Tom Lane)

E.56.3.3.2. CREATE TABLE

- Add support for copying COMMENTS and STORAGE settings in CREATE TABLE ... LIKE commands (Itagaki Takahiro)
- Add a shortcut for copying all properties in CREATE TABLE ... LIKE commands (Itagaki Takahiro)
- Add the SQL-standard CREATE TABLE ... OF *type* command (Peter Eisentraut)

This allows creation of a table that matches an existing composite type. Additional constraints and defaults can be specified in the command.

E.56.3.3.3. Constraints

- Add deferrable unique constraints (Dean Rasheed)

  This allows mass updates, such as `UPDATE tab SET col = col + 1`, to work reliably on columns that have unique indexes or are marked as primary keys. If the constraint is specified as `DEFERRABLE` it will be checked at the end of the statement, rather than after each row is updated. The constraint check can also be deferred until the end of the current transaction, allowing such updates to be spread over multiple SQL commands.

- Add exclusion constraints (Jeff Davis)

  Exclusion constraints generalize uniqueness constraints by allowing arbitrary comparison operators, not just equality. They are created with the `CREATE TABLE CONSTRAINT ... EXCLUDE` clause. The most common use of exclusion constraints is to specify that column entries must not overlap, rather than simply not be equal. This is useful for time periods and other ranges, as well as arrays. This feature enhances checking of data integrity for many calendaring, time-management, and scientific applications.

- Improve uniqueness-constraint violation error messages to report the values causing the failure (Itagaki Takahiro)

  For example, a uniqueness constraint violation might now report `Key (x)=(2) already exists`.

E.56.3.3.4. Object Permissions

- Add the ability to make mass permission changes across a whole schema using the new `GRANT`/`REVOKE IN SCHEMA` clause (Petr Jelinek)

  This simplifies management of object permissions and makes it easier to utilize database roles for application data security.

- Add `ALTER DEFAULT PRIVILEGES` command to control privileges of objects created later (Petr Jelinek)

  This greatly simplifies the assignment of object privileges in a complex database application. Default privileges can be set for tables, views, sequences, and functions. Defaults may be assigned on a per-schema basis, or database-wide.

- Add the ability to control large object (BLOB) permissions with `GRANT`/`REVOKE` (KaiGai Kohei)

  Formerly, any database user could read or modify any large object. Read and write permissions can now be granted and revoked per large object, and the ownership of large objects is tracked.

E.56.3.4. Utility Operations

- Make `LISTEN`/`NOTIFY` store pending events in a memory queue, rather than in a system table (Joachim Wieland)

This substantially improves performance, while retaining the existing features of transactional support and guaranteed delivery.

- Allow `NOTIFY` to pass an optional "payload" string to listeners (Joachim Wieland)

  This greatly improves the usefulness of `LISTEN`/`NOTIFY` as a general-purpose event queue system.

- Allow `CLUSTER` on all per-database system catalogs (Tom Lane)

  Shared catalogs still cannot be clustered.

E.56.3.4.1. COPY

- Accept `COPY ... CSV FORCE QUOTE *` (Itagaki Takahiro)

  Now `*` can be used as shorthand for "all columns" in the `FORCE QUOTE` clause.

- Add new `COPY` syntax that allows options to be specified inside parentheses (Robert Haas, Emmanuel Cecchet)

  This allows greater flexibility for future `COPY` options. The old syntax is still supported, but only for pre-existing options.

E.56.3.4.2. EXPLAIN

- Allow `EXPLAIN` to output in XML, JSON, or YAML format (Robert Haas, Greg Sabino Mullane)

  The new output formats are easily machine-readable, supporting the development of new tools for analysis of `EXPLAIN` output.

- Add new `BUFFERS` option to report query buffer usage during `EXPLAIN ANALYZE` (Itagaki Takahiro)

  This allows better query profiling for individual queries. Buffer usage is no longer reported in the output for log_statement_stats and related settings.

- Add hash usage information to `EXPLAIN` output (Robert Haas)

- Add new `EXPLAIN` syntax that allows options to be specified inside parentheses (Robert Haas)

  This allows greater flexibility for future `EXPLAIN` options. The old syntax is still supported, but only for pre-existing options.

E.56.3.4.3. VACUUM

- Change `VACUUM FULL` to rewrite the entire table and rebuild its indexes, rather than moving individual rows around to compact space (Itagaki Takahiro, Tom Lane)

  The previous method was usually slower and caused index bloat. Note that the new method will use more disk space transiently during `VACUUM FULL`; potentially as much as twice the space normally occupied by the table and its indexes.

- Add new `VACUUM` syntax that allows options to be specified inside parentheses (Itagaki Takahiro)

  This allows greater flexibility for future `VACUUM` options. The old syntax is still supported, but only for pre-existing options.

E.56.3.4.4. Indexes

- Allow an index to be named automatically by omitting the index name in `CREATE INDEX` (Tom Lane)
- By default, multicolumn indexes are now named after all their columns; and index expression columns are now named based on their expressions (Tom Lane)
- Reindexing shared system catalogs is now fully transactional and crash-safe (Tom Lane)

  Formerly, reindexing a shared index was only allowed in standalone mode, and a crash during the operation could leave the index in worse condition than it was before.
- Add `point_ops` operator class for GiST (Teodor Sigaev)

  This feature permits GiST indexing of `point` columns. The index can be used for several types of queries such as *`point`* `<@` *`polygon`* (point is in polygon). This should make many PostGIS queries faster.
- Use red-black binary trees for GIN index creation (Teodor Sigaev)

  Red-black trees are self-balancing. This avoids slowdowns in cases where the input is in nonrandom order.

E.56.3.5. Data Types

- Allow `bytea` values to be written in hex notation (Peter Eisentraut)

  The server parameter `bytea_output` controls whether hex or traditional format is used for `bytea` output. Libpq's `PQescapeByteaConn()` function automatically uses the hex format when connected to PostgreSQL 9.0 or newer servers. However, pre-9.0 libpq versions will not correctly process hex format from newer servers.

  The new hex format will be directly compatible with more applications that use binary data, allowing them to store and retrieve it without extra conversion. It is also significantly faster to read and write than the traditional format.
- Allow server parameter extra_float_digits to be increased to `3` (Tom Lane)

  The previous maximum `extra_float_digits` setting was `2`. There are cases where 3 digits are needed to dump and restore `float4` values exactly. pg_dump will now use the setting of 3 when dumping from a server that allows it.
- Tighten input checking for `int2vector` values (Caleb Welton)

E.56.3.5.1. Full Text Search

- Add prefix support in `synonym` dictionaries (Teodor Sigaev)
- Add *filtering* dictionaries (Teodor Sigaev)

  Filtering dictionaries allow tokens to be modified then passed to subsequent dictionaries.
- Allow underscores in email-address tokens (Teodor Sigaev)
- Use more standards-compliant rules for parsing URL tokens (Tom Lane)

E.56.3.6. Functions

- Allow function calls to supply parameter names and match them to named parameters in the function definition (Pavel Stehule)

  For example, if a function is defined to take parameters `a` and `b`, it can be called with `func(a := 7, b := 12)` or `func(b := 12, a := 7)`.

- Support locale-specific regular expression processing with UTF-8 server encoding (Tom Lane)

  Locale-specific regular expression functionality includes case-insensitive matching and locale-specific character classes. Previously, these features worked correctly for non-ASCII characters only if the database used a single-byte server encoding (such as LATIN1). They will still misbehave in multi-byte encodings other than UTF-8.

- Add support for scientific notation in `to_char()` (`EEEE` specification) (Pavel Stehule, Brendan Jurd)

- Make `to_char()` honor `FM` (fill mode) in `Y`, `YY`, and `YYY` specifications (Bruce Momjian, Tom Lane)

  It was already honored by `YYYY`.

- Fix `to_char()` to output localized numeric and monetary strings in the correct encoding on Windows (Hiroshi Inoue, Itagaki Takahiro, Bruce Momjian)

- Correct calculations of "overlaps" and "contains" operations for polygons (Teodor Sigaev)

  The polygon `&&` (overlaps) operator formerly just checked to see if the two polygons' bounding boxes overlapped. It now does a more correct check. The polygon `@>` and `<@` (contains/contained by) operators formerly checked to see if one polygon's vertexes were all contained in the other; this can wrongly report "true" for some non-convex polygons. Now they check that all line segments of one polygon are contained in the other.

E.56.3.6.1. Aggregates

- Allow aggregate functions to use `ORDER BY` (Andrew Gierth)

  For example, this is now supported: `array_agg(a ORDER BY b)`. This is useful with aggregates for which the order of input values is significant, and eliminates the need to use a nonstandard subquery to determine the ordering.

- Multi-argument aggregate functions can now use `DISTINCT` (Andrew Gierth)

- Add the `string_agg()` aggregate function to combine values into a single string (Pavel Stehule)

- Aggregate functions that are called with `DISTINCT` are now passed NULL values if the aggregate transition function is not marked as `STRICT` (Andrew Gierth)

  For example, `agg(DISTINCT x)` might pass a NULL `x` value to `agg()`. This is more consistent with the behavior in non-`DISTINCT` cases.

E.56.3.6.2. Bit Strings

- Add `get_bit()` and `set_bit()` functions for `bit` strings, mirroring those for `bytea` (Leonardo F)

- Implement `OVERLAY()` (replace) for `bit` strings and `bytea` (Leonardo F)

E.56.3.6.3. Object Information Functions

- Add `pg_table_size()` and `pg_indexes_size()` to provide a more user-friendly interface to the `pg_relation_size()` function (Bernd Helmle)
- Add `has_sequence_privilege()` for sequence permission checking (Abhijit Menon-Sen)
- Update the information_schema views to conform to SQL:2008 (Peter Eisentraut)
- Make the `information_schema` views correctly display maximum octet lengths for `char` and `varchar` columns (Peter Eisentraut)
- Speed up `information_schema` privilege views (Joachim Wieland)

E.56.3.6.4. Function and Trigger Creation

- Support execution of anonymous code blocks using the `DO` statement (Petr Jelinek, Joshua Tolley, Hannu Valtonen)

  This allows execution of server-side code without the need to create and delete a temporary function definition. Code can be executed in any language for which the user has permissions to define a function.
- Implement SQL-standard-compliant per-column triggers (Itagaki Takahiro)

  Such triggers are fired only when the specified column(s) are affected by the query, e.g. appear in an `UPDATE`'s `SET` list.
- Add the `WHEN` clause to `CREATE TRIGGER` to allow control over whether a trigger is fired (Itagaki Takahiro)

  While the same type of check can always be performed inside the trigger, doing it in an external `WHEN` clause can have performance benefits.

E.56.3.7. Server-Side Languages

- Add the `OR REPLACE` clause to `CREATE LANGUAGE` (Tom Lane)

  This is helpful to optionally install a language if it does not already exist, and is particularly helpful now that PL/pgSQL is installed by default.

E.56.3.7.1. PL/pgSQL Server-Side Language

- Install PL/pgSQL by default (Bruce Momjian)

  The language can still be removed from a particular database if the administrator has security or performance concerns about making it available.
- Improve handling of cases where PL/pgSQL variable names conflict with identifiers used in queries within a function (Tom Lane)

  The default behavior is now to throw an error when there is a conflict, so as to avoid surprising behaviors. This can be modified, via the configuration parameter `plpgsql.variable_conflict` or the per-function option `#variable_conflict`, to allow either the variable or the query-supplied column to be used. In any case PL/pgSQL will no longer attempt to substitute variables in places where they would not be syntactically valid.

- Make PL/pgSQL use the main lexer, rather than its own version (Tom Lane)

  This ensures accurate tracking of the main system's behavior for details such as string escaping. Some user-visible details, such as the set of keywords considered reserved in PL/pgSQL, have changed in consequence.

- Avoid throwing an unnecessary error for an invalid record reference (Tom Lane)

  An error is now thrown only if the reference is actually fetched, rather than whenever the enclosing expression is reached. For example, many people have tried to do this in triggers:

  ```
  if TG_OP = 'INSERT' and NEW.col1 = ... then
  ```

  This will now actually work as expected.

- Improve PL/pgSQL's ability to handle row types with dropped columns (Pavel Stehule)

- Allow input parameters to be assigned values within PL/pgSQL functions (Steve Prentice)

  Formerly, input parameters were treated as being declared `CONST`, so the function's code could not change their values. This restriction has been removed to simplify porting of functions from other DBMSes that do not impose the equivalent restriction. An input parameter now acts like a local variable initialized to the passed-in value.

- Improve error location reporting in PL/pgSQL (Tom Lane)

- Add *`count`* and `ALL` options to `MOVE FORWARD`/`BACKWARD` in PL/pgSQL (Pavel Stehule)

- Allow PL/pgSQL's `WHERE CURRENT OF` to use a cursor variable (Tom Lane)

- Allow PL/pgSQL's `OPEN` *`cursor`* `FOR EXECUTE` to use parameters (Pavel Stehule, Itagaki Takahiro)

  This is accomplished with a new `USING` clause.

E.56.3.7.2. PL/Perl Server-Side Language

- Add new PL/Perl functions: `quote_literal()`, `quote_nullable()`, `quote_ident()`, `encode_bytea()`, `decode_bytea()`, `looks_like_number()`, `encode_array_literal()`, `encode_array_constructor()` (Tim Bunce)

- Add server parameter `plperl.on_init` to specify a PL/Perl initialization function (Tim Bunce)

  `plperl.on_plperl_init` and `plperl.on_plperlu_init` are also available for initialization that is specific to the trusted or untrusted language respectively.

- Support `END` blocks in PL/Perl (Tim Bunce)

  `END` blocks do not currently allow database access.

- Allow `use strict` in PL/Perl (Tim Bunce)

  Perl `strict` checks can also be globally enabled with the new server parameter `plperl.use_strict`.

- Allow `require` in PL/Perl (Tim Bunce)

  This basically tests to see if the module is loaded, and if not, generates an error. It will not allow loading of modules that the administrator has not preloaded via the initialization parameters.

- Allow `use feature` in PL/Perl if Perl version 5.10 or later is used (Tim Bunce)

- Verify that PL/Perl return values are valid in the server encoding (Andrew Dunstan)

E.56.3.7.3. PL/Python Server-Side Language

- Add Unicode support in PL/Python (Peter Eisentraut)

  Strings are automatically converted from/to the server encoding as necessary.

- Improve `bytea` support in PL/Python (Caleb Welton)

  `Bytea` values passed into PL/Python are now represented as binary, rather than the PostgreSQL `bytea` text format. `Bytea` values containing null bytes are now also output properly from PL/Python. Passing of boolean, integer, and float values was also improved.

- Support arrays as parameters and return values in PL/Python (Peter Eisentraut)

- Improve mapping of SQL domains to Python types (Peter Eisentraut)

- Add Python 3 support to PL/Python (Peter Eisentraut)

  The new server-side language is called `plpython3u`. This cannot be used in the same session with the Python 2 server-side language.

- Improve error location and exception reporting in PL/Python (Peter Eisentraut)

E.56.3.8. Client Applications

- Add an `--analyze-only` option to `vacuumdb`, to analyze without vacuuming (Bruce Momjian)

E.56.3.8.1. psql

- Add support for quoting/escaping the values of psql variables as SQL strings or identifiers (Pavel Stehule, Robert Haas)

  For example, `:'var'` will produce the value of `var` quoted and properly escaped as a literal string, while `:"var"` will produce its value quoted and escaped as an identifier.

- Ignore a leading UTF-8-encoded Unicode byte-order marker in script files read by psql (Itagaki Takahiro)

  This is enabled when the client encoding is UTF-8. It improves compatibility with certain editors, mostly on Windows, that insist on inserting such markers.

- Fix `psql --file -` to properly honor `--single-transaction` (Bruce Momjian)

- Avoid overwriting of psql's command-line history when two psql sessions are run concurrently (Tom Lane)

- Improve psql's tab completion support (Itagaki Takahiro)

- Show `\timing` output when it is enabled, regardless of "quiet" mode (Peter Eisentraut)

E.56.3.8.1.1. psql Display

- Improve display of wrapped columns in psql (Roger Leigh)

  This behavior is now the default. The previous formatting is available by using `\pset linestyle old-ascii`.

- Allow psql to use fancy Unicode line-drawing characters via `\pset linestyle unicode` (Roger Leigh)

E.56.3.8.1.2. psql `\d` Commands

- Make `\d` show child tables that inherit from the specified parent (Damien Clochard)

  `\d` shows only the number of child tables, while `\d+` shows the names of all child tables.

- Show definitions of index columns in `\d index_name` (Khee Chin)

  The definition is useful for expression indexes.

- Show a view's defining query only in `\d+`, not in `\d` (Peter Eisentraut)

  Always including the query was deemed overly verbose.

E.56.3.8.2. pg_dump

- Make pg_dump/pg_restore `--clean` also remove large objects (Itagaki Takahiro)
- Fix pg_dump to properly dump large objects when `standard_conforming_strings` is enabled (Tom Lane)

  The previous coding could fail when dumping to an archive file and then generating script output from pg_restore.

- pg_restore now emits large-object data in hex format when generating script output (Tom Lane)

  This could cause compatibility problems if the script is then loaded into a pre-9.0 server. To work around that, restore directly to the server, instead.

- Allow pg_dump to dump comments attached to columns of composite types (Taro Minowa (Higepon))
- Make pg_dump `--verbose` output the pg_dump and server versions in text output mode (Jim Cox, Tom Lane)

  These were already provided in custom output mode.

- pg_restore now complains if any command-line arguments remain after the switches and optional file name (Tom Lane)

  Previously, it silently ignored any such arguments.

E.56.3.8.3. pg_ctl

- Allow pg_ctl to be used safely to start the postmaster during a system reboot (Tom Lane)

  Previously, pg_ctl's parent process could have been mistakenly identified as a running postmaster based on a stale postmaster lock file, resulting in a transient failure to start the database.

- Give pg_ctl the ability to initialize the database (by invoking initdb) (Zdenek Kotala)

E.56.3.9. Development Tools

E.56.3.9.1. libpq

- Add new libpq functions `PQconnectdbParams()` and `PQconnectStartParams()` (Guillaume Lelarge)

  These functions are similar to `PQconnectdb()` and `PQconnectStart()` except that they accept a null-terminated array of connection options, rather than requiring all options to be provided in a single string.

- Add libpq functions `PQescapeLiteral()` and `PQescapeIdentifier()` (Robert Haas)

  These functions return appropriately quoted and escaped SQL string literals and identifiers. The caller is not required to pre-allocate the string result, as is required by `PQescapeStringConn()`.

- Add support for a per-user service file (`.pg_service.conf`), which is checked before the site-wide service file (Peter Eisentraut)
- Properly report an error if the specified libpq service cannot be found (Peter Eisentraut)
- Add TCP keepalive settings in libpq (Tollef Fog Heen, Fujii Masao, Robert Haas)

  Keepalive settings were already supported on the server end of TCP connections.

- Avoid extra system calls to block and unblock `SIGPIPE` in libpq, on platforms that offer alternative methods (Jeremy Kerr)
- When a `.pgpass`-supplied password fails, mention where the password came from in the error message (Bruce Momjian)
- Load all SSL certificates given in the client certificate file (Tom Lane)

  This improves support for indirectly-signed SSL certificates.

E.56.3.9.2. ecpg

- Add SQLDA (SQL Descriptor Area) support to ecpg (Boszormenyi Zoltan)
- Add the `DESCRIBE` [`OUTPUT`] statement to ecpg (Boszormenyi Zoltan)
- Add an ECPGtransactionStatus function to return the current transaction status (Bernd Helmle)
- Add the `string` data type in ecpg Informix-compatibility mode (Boszormenyi Zoltan)
- Allow ecpg to use `new` and `old` variable names without restriction (Michael Meskes)
- Allow ecpg to use variable names in `free()` (Michael Meskes)
- Make `ecpg_dynamic_type()` return zero for non-SQL3 data types (Michael Meskes)

  Previously it returned the negative of the data type OID. This could be confused with valid type OIDs, however.

- Support `long long` types on platforms that already have 64-bit `long` (Michael Meskes)

E.56.3.9.2.1. ecpg Cursors

- Add out-of-scope cursor support in ecpg's native mode (Boszormenyi Zoltan)

  This allows `DECLARE` to use variables that are not in scope when `OPEN` is called. This facility already existed in ecpg's Informix-compatibility mode.

- Allow dynamic cursor names in ecpg (Boszormenyi Zoltan)
- Allow ecpg to use noise words `FROM` and `IN` in `FETCH` and `MOVE` (Boszormenyi Zoltan)

E.56.3.10. Build Options

- Enable client thread safety by default (Bruce Momjian)

  The thread-safety option can be disabled with `configure --disable-thread-safety`.
- Add support for controlling the Linux out-of-memory killer (Alex Hunsaker, Tom Lane)

  Now that `/proc/self/oom_adj` allows disabling of the Linux out-of-memory (OOM) killer, it's recommendable to disable OOM kills for the postmaster. It may then be desirable to re-enable OOM kills for the postmaster's child processes. The new compile-time option `LINUX_OOM_ADJ` allows the killer to be reactivated for child processes.

E.56.3.10.1. Makefiles

- New `Makefile` targets `world`, `install-world`, and `installcheck-world` (Andrew Dunstan)

  These are similar to the existing `all`, `install`, and `installcheck` targets, but they also build the HTML documentation, build and test `contrib`, and test server-side languages and ecpg.
- Add data and documentation installation location control to PGXS Makefiles (Mark Cave-Ayland)
- Add Makefile rules to build the PostgreSQL documentation as a single HTML file or as a single plain-text file (Peter Eisentraut, Bruce Momjian)

E.56.3.10.2. Windows

- Support compiling on 64-bit Windows and running in 64-bit mode (Tsutomu Yamada, Magnus Hagander)

  This allows for large shared memory sizes on Windows.
- Support server builds using Visual Studio 2008 (Magnus Hagander)

E.56.3.11. Source Code

- Distribute prebuilt documentation in a subdirectory tree, rather than as tar archive files inside the distribution tarball (Peter Eisentraut)

  For example, the prebuilt HTML documentation is now in `doc/src/sgml/html/`; the manual pages are packaged similarly.
- Make the server's lexer reentrant (Tom Lane)

  This was needed for use of the lexer by PL/pgSQL.
- Improve speed of memory allocation (Tom Lane, Greg Stark)

- User-defined constraint triggers now have entries in `pg_constraint` as well as `pg_trigger` (Tom Lane)

  Because of this change, `pg_constraint.pgconstrname` is now redundant and has been removed.

- Add system catalog columns `pg_constraint.conindid` and `pg_trigger.tgconstrindid` to better document the use of indexes for constraint enforcement (Tom Lane)

- Allow multiple conditions to be communicated to backends using a single operating system signal (Fujii Masao)

  This allows new features to be added without a platform-specific constraint on the number of signal conditions.

- Improve source code test coverage, including `contrib`, PL/Python, and PL/Perl (Peter Eisentraut, Andrew Dunstan)

- Remove the use of flat files for system table bootstrapping (Tom Lane, Alvaro Herrera)

  This improves performance when using many roles or databases, and eliminates some possible failure conditions.

- Automatically generate the initial contents of `pg_attribute` for "bootstrapped" catalogs (John Naylor)

  This greatly simplifies changes to these catalogs.

- Split the processing of `INSERT`/`UPDATE`/`DELETE` operations out of `execMain.c` (Marko Tiikkaja)

  Updates are now executed in a separate ModifyTable node. This change is necessary infrastructure for future improvements.

- Simplify translation of psql's SQL help text (Peter Eisentraut)

- Reduce the lengths of some file names so that all file paths in the distribution tarball are less than 100 characters (Tom Lane)

  Some decompression programs have problems with longer file paths.

- Add a new `ERRCODE_INVALID_PASSWORD` `SQLSTATE` error code (Bruce Momjian)

- With authors' permissions, remove the few remaining personal source code copyright notices (Bruce Momjian)

  The personal copyright notices were insignificant but the community occasionally had to answer questions about them.

- Add new documentation section about running PostgreSQL in non-durable mode to improve performance (Bruce Momjian)

- Restructure the HTML documentation `Makefile` rules to make their dependency checks work correctly, avoiding unnecessary rebuilds (Peter Eisentraut)

- Use DocBook XSL stylesheets for man page building, rather than Docbook2X (Peter Eisentraut)

  This changes the set of tools needed to build the man pages.

- Improve PL/Perl code structure (Tim Bunce)

- Improve error context reports in PL/Perl (Alexey Klyukin)

E.56.3.11.1. New Build Requirements

Note that these requirements do not apply when building from a distribution tarball, since tarballs include the files that these programs are used to build.

- Require Autoconf 2.63 to build configure (Peter Eisentraut)
- Require Flex 2.5.31 or later to build from a CVS checkout (Tom Lane)
- Require Perl version 5.8 or later to build from a CVS checkout (John Naylor, Andrew Dunstan)

E.56.3.11.2. Portability

- Use a more modern API for Bonjour (Tom Lane)

  Bonjour support now requires OS X 10.3 or later. The older API has been deprecated by Apple.
- Add spinlock support for the SuperH architecture (Nobuhiro Iwamatsu)
- Allow non-GCC compilers to use inline functions if they support them (Kurt Harriman)
- Remove support for platforms that don't have a working 64-bit integer data type (Tom Lane)
- Restructure use of `LDFLAGS` to be more consistent across platforms (Tom Lane)

  `LDFLAGS` is now used for linking both executables and shared libraries, and we add on `LDFLAGS_EX` when linking executables, or `LDFLAGS_SL` when linking shared libraries.

E.56.3.11.3. Server Programming

- Make backend header files safe to include in C++ (Kurt Harriman, Peter Eisentraut)

  These changes remove keyword conflicts that previously made C++ usage difficult in backend code. However, there are still other complexities when using C++ for backend functions. `extern "C" { }` is still necessary in appropriate places, and memory management and error handling are still problematic.
- Add `AggCheckCallContext()` for use in detecting if a C function is being called as an aggregate (Hitoshi Harada)
- Change calling convention for `SearchSysCache()` and related functions to avoid hard-wiring the maximum number of cache keys (Robert Haas)

  Existing calls will still work for the moment, but can be expected to break in 9.1 or later if not converted to the new style.
- Require calls of `fastgetattr()` and `heap_getattr()` backend macros to provide a non-NULL fourth argument (Robert Haas)
- Custom typanalyze functions should no longer rely on `VacAttrStats.attr` to determine the type of data they will be passed (Tom Lane)

  This was changed to allow collection of statistics on index columns for which the storage type is different from the underlying column data type. There are new fields that tell the actual datatype being analyzed.

E.56.3.11.4. Server Hooks

- Add parser hooks for processing ColumnRef and ParamRef nodes (Tom Lane)
- Add a ProcessUtility hook so loadable modules can control utility commands (Itagaki Takahiro)

E.56.3.11.5. Binary Upgrade Support

- Add `contrib/pg_upgrade` to support in-place upgrades (Bruce Momjian)

  This avoids the requirement of dumping/reloading the database when upgrading to a new major release of PostgreSQL, thus reducing downtime by orders of magnitude. It supports upgrades to 9.0 from PostgreSQL 8.3 and 8.4.
- Add support for preserving relation `relfilenode` values during binary upgrades (Bruce Momjian)
- Add support for preserving `pg_type` and `pg_enum` OIDs during binary upgrades (Bruce Momjian)
- Move data files within tablespaces into PostgreSQL-version-specific subdirectories (Bruce Momjian)

  This simplifies binary upgrades.

E.56.3.12. Contrib

- Add multithreading option (`-j`) to `contrib/pgbench` (Itagaki Takahiro)

  This allows multiple CPUs to be used by pgbench, reducing the risk of pgbench itself becoming the test bottleneck.
- Add `\shell` and `\setshell` meta commands to `contrib/pgbench` (Michael Paquier)
- New features for `contrib/dict_xsyn` (Sergey Karpov)

  The new options are `matchorig`, `matchsynonyms`, and `keepsynonyms`.
- Add full text dictionary `contrib/unaccent` (Teodor Sigaev)

  This filtering dictionary removes accents from letters, which makes full-text searches over multiple languages much easier.
- Add `dblink_get_notify()` to `contrib/dblink` (Marcus Kempe)

  This allows asynchronous notifications in dblink.
- Improve `contrib/dblink`'s handling of dropped columns (Tom Lane)

  This affects `dblink_build_sql_insert()` and related functions. These functions now number columns according to logical not physical column numbers.
- Greatly increase `contrib/hstore`'s data length limit, and add B-tree and hash support so `GROUP BY` and `DISTINCT` operations are possible on `hstore` columns (Andrew Gierth)

  New functions and operators were also added. These improvements make `hstore` a full-function key-value store embedded in PostgreSQL.
- Add `contrib/passwordcheck` to support site-specific password strength policies (Laurenz Albe)

  The source code of this module should be modified to implement site-specific password policies.
- Add `contrib/pg_archivecleanup` tool (Simon Riggs)

  This is designed to be used in the `archive_cleanup_command` server parameter, to remove no-longer-needed archive files.
- Add query text to `contrib/auto_explain` output (Andrew Dunstan)
- Add buffer access counters to `contrib/pg_stat_statements` (Itagaki Takahiro)

- Update `contrib/start-scripts/linux` to use `/proc/self/oom_adj` to disable the Linux out-of-memory (OOM) killer (Alex Hunsaker, Tom Lane)

E.57. Release 8.4.22

Release Date: 2014-07-24

This release contains a variety of fixes from 8.4.21. For information about new features in the 8.4 major release, see Section E.79.

This is expected to be the last PostgreSQL release in the 8.4.X series. Users are encouraged to update to a newer release branch soon.

E.57.1. Migration to Version 8.4.22

A dump/restore is not required for those running 8.4.X.

However, this release corrects an index corruption problem in some GiST indexes. See the first changelog entry below to find out whether your installation has been affected and what steps you should take if so.

Also, if you are upgrading from a version earlier than 8.4.19, see Section E.60.

E.57.2. Changes

- Correctly initialize padding bytes in `contrib/btree_gist` indexes on `bit` columns (Heikki Linnakangas)

  This error could result in incorrect query results due to values that should compare equal not being seen as equal. Users with GiST indexes on `bit` or `bit varying` columns should `REINDEX` those indexes after installing this update.

- Protect against torn pages when deleting GIN list pages (Heikki Linnakangas)

  This fix prevents possible index corruption if a system crash occurs while the page update is being written to disk.

- Fix possibly-incorrect cache invalidation during nested calls to `ReceiveSharedInvalidMessages` (Andres Freund)

- Don't assume a subquery's output is unique if there's a set-returning function in its targetlist (David Rowley)

  This oversight could lead to misoptimization of constructs like `WHERE x IN (SELECT y, generate_series(1,10) FROM t GROUP BY y)`.

- Fix failure to detoast fields in composite elements of structured types (Tom Lane)

  This corrects cases where TOAST pointers could be copied into other tables without being dereferenced. If the original data is later deleted, it would lead to errors like "missing chunk number 0 for toast value ..." when the now-dangling pointer is used.

- Fix "record type has not been registered" failures with whole-row references to the output of Append plan nodes (Tom Lane)
- Fix possible crash when invoking a user-defined function while rewinding a cursor (Tom Lane)
- Fix query-lifespan memory leak while evaluating the arguments for a function in `FROM` (Tom Lane)
- Fix session-lifespan memory leaks in regular-expression processing (Tom Lane, Arthur O'Dwyer, Greg Stark)
- Fix data encoding error in `hungarian.stop` (Tom Lane)
- Fix liveness checks for rows that were inserted in the current transaction and then deleted by a now-rolled-back subtransaction (Andres Freund)

  This could cause problems (at least spurious warnings, and at worst an infinite loop) if `CREATE INDEX` or `CLUSTER` were done later in the same transaction.
- Clear `pg_stat_activity.xact_start` during `PREPARE TRANSACTION` (Andres Freund)

  After the `PREPARE`, the originating session is no longer in a transaction, so it should not continue to display a transaction start time.
- Fix `REASSIGN OWNED` to not fail for text search objects (Álvaro Herrera)
- Block signals during postmaster startup (Tom Lane)

  This ensures that the postmaster will properly clean up after itself if, for example, it receives SIGINT while still starting up.
- Secure Unix-domain sockets of temporary postmasters started during `make check` (Noah Misch)

  Any local user able to access the socket file could connect as the server's bootstrap superuser, then proceed to execute arbitrary code as the operating-system user running the test, as we previously noted in CVE-2014-0067. This change defends against that risk by placing the server's socket in a temporary, mode 0700 subdirectory of `/tmp`. The hazard remains however on platforms where Unix sockets are not supported, notably Windows, because then the temporary postmaster must accept local TCP connections.

  A useful side effect of this change is to simplify `make check` testing in builds that override `DEFAULT_PGSOCKET_DIR`. Popular non-default values like `/var/run/postgresql` are often not writable by the build user, requiring workarounds that will no longer be necessary.
- On Windows, allow new sessions to absorb values of PGC_BACKEND parameters (such as log_connections) from the configuration file (Amit Kapila)

  Previously, if such a parameter were changed in the file post-startup, the change would have no effect.
- Properly quote executable path names on Windows (Nikhil Deshpande)

  This oversight could cause initdb and pg_upgrade to fail on Windows, if the installation path contained both spaces and `@` signs.
- Fix linking of libpython on OS X (Tom Lane)

  The method we previously used can fail with the Python library supplied by Xcode 5.0 and later.
- Avoid buffer bloat in libpq when the server consistently sends data faster than the client can absorb it (Shin-ichi Morita, Tom Lane)

  libpq could be coerced into enlarging its input buffer until it runs out of memory (which would be reported misleadingly as "lost synchronization with server"). Under ordinary circumstances it's quite far-fetched that data could be continuously transmitted more quickly than the `recv()`

loop can absorb it, but this has been observed when the client is artificially slowed by scheduler constraints.

- Ensure that LDAP lookup attempts in libpq time out as intended (Laurenz Albe)
- Fix pg_restore's processing of old-style large object comments (Tom Lane)

  A direct-to-database restore from an archive file generated by a pre-9.0 version of pg_dump would usually fail if the archive contained more than a few comments for large objects.
- In `contrib/pgcrypto` functions, ensure sensitive information is cleared from stack variables before returning (Marko Kreen)
- In `contrib/uuid-ossp`, cache the state of the OSSP UUID library across calls (Tom Lane)

  This improves the efficiency of UUID generation and reduces the amount of entropy drawn from `/dev/urandom`, on platforms that have that.
- Update time zone data files to tzdata release 2014e for DST law changes in Crimea, Egypt, and Morocco.

E.58. Release 8.4.21

Release Date: 2014-03-20

This release contains a variety of fixes from 8.4.20. For information about new features in the 8.4 major release, see Section E.79.

The PostgreSQL community will stop releasing updates for the 8.4.X release series in July 2014. Users are encouraged to update to a newer release branch soon.

E.58.1. Migration to Version 8.4.21

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.19, see Section E.60.

E.58.2. Changes

- Restore GIN metapages unconditionally to avoid torn-page risk (Heikki Linnakangas)

  Although this oversight could theoretically result in a corrupted index, it is unlikely to have caused any problems in practice, since the active part of a GIN metapage is smaller than a standard 512-byte disk sector.
- Allow regular-expression operators to be terminated early by query cancel requests (Tom Lane)

  This prevents scenarios wherein a pathological regular expression could lock up a server process uninterruptably for a long time.
- Remove incorrect code that tried to allow `OVERLAPS` with single-element row arguments (Joshua Yanovski)

This code never worked correctly, and since the case is neither specified by the SQL standard nor documented, it seemed better to remove it than fix it.

- Avoid getting more than `AccessShareLock` when de-parsing a rule or view (Dean Rasheed)

  This oversight resulted in pg_dump unexpectedly acquiring `RowExclusiveLock` locks on tables mentioned as the targets of `INSERT`/`UPDATE`/`DELETE` commands in rules. While usually harmless, that could interfere with concurrent transactions that tried to acquire, for example, `ShareLock` on those tables.

- Prevent interrupts while reporting non-`ERROR` messages (Tom Lane)

  This guards against rare server-process freezeups due to recursive entry to `syslog()`, and perhaps other related problems.

- Update time zone data files to tzdata release 2014a for DST law changes in Fiji and Turkey, plus historical changes in Israel and Ukraine.

E.59. Release 8.4.20

Release Date: 2014-02-20

This release contains a variety of fixes from 8.4.19. For information about new features in the 8.4 major release, see Section E.79.

The PostgreSQL community will stop releasing updates for the 8.4.X release series in July 2014. Users are encouraged to update to a newer release branch soon.

E.59.1. Migration to Version 8.4.20

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.19, see Section E.60.

E.59.2. Changes

- Shore up `GRANT ... WITH ADMIN OPTION` restrictions (Noah Misch)

  Granting a role without `ADMIN OPTION` is supposed to prevent the grantee from adding or removing members from the granted role, but this restriction was easily bypassed by doing `SET ROLE` first. The security impact is mostly that a role member can revoke the access of others, contrary to the wishes of his grantor. Unapproved role member additions are a lesser concern, since an uncooperative role member could provide most of his rights to others anyway by creating views or `SECURITY DEFINER` functions. (CVE-2014-0060)

- Prevent privilege escalation via manual calls to PL validator functions (Andres Freund)

  The primary role of PL validator functions is to be called implicitly during `CREATE FUNCTION`, but they are also normal SQL functions that a user can call explicitly. Calling a validator on a function actually written in some other language was not checked for and could be exploited for privilege-escalation purposes. The fix involves adding a call to a privilege-checking function in

each validator function. Non-core procedural languages will also need to make this change to their own validator functions, if any. (CVE-2014-0061)

- Avoid multiple name lookups during table and index DDL (Robert Haas, Andres Freund)

  If the name lookups come to different conclusions due to concurrent activity, we might perform some parts of the DDL on a different table than other parts. At least in the case of `CREATE INDEX`, this can be used to cause the permissions checks to be performed against a different table than the index creation, allowing for a privilege escalation attack. (CVE-2014-0062)

- Prevent buffer overrun with long datetime strings (Noah Misch)

  The `MAXDATELEN` constant was too small for the longest possible value of type `interval`, allowing a buffer overrun in `interval_out()`. Although the datetime input functions were more careful about avoiding buffer overrun, the limit was short enough to cause them to reject some valid inputs, such as input containing a very long timezone name. The ecpg library contained these vulnerabilities along with some of its own. (CVE-2014-0063)

- Prevent buffer overrun due to integer overflow in size calculations (Noah Misch, Heikki Linnakangas)

  Several functions, mostly type input functions, calculated an allocation size without checking for overflow. If overflow did occur, a too-small buffer would be allocated and then written past. (CVE-2014-0064)

- Prevent overruns of fixed-size buffers (Peter Eisentraut, Jozef Mlich)

  Use `strlcpy()` and related functions to provide a clear guarantee that fixed-size buffers are not overrun. Unlike the preceding items, it is unclear whether these cases really represent live issues, since in most cases there appear to be previous constraints on the size of the input string. Nonetheless it seems prudent to silence all Coverity warnings of this type. (CVE-2014-0065)

- Avoid crashing if `crypt()` returns NULL (Honza Horak, Bruce Momjian)

  There are relatively few scenarios in which `crypt()` could return NULL, but `contrib/chkpass` would crash if it did. One practical case in which this could be an issue is if libc is configured to refuse to execute unapproved hashing algorithms (e.g., "FIPS mode"). (CVE-2014-0066)

- Document risks of `make check` in the regression testing instructions (Noah Misch, Tom Lane)

  Since the temporary server started by `make check` uses "trust" authentication, another user on the same machine could connect to it as database superuser, and then potentially exploit the privileges of the operating-system user who started the tests. A future release will probably incorporate changes in the testing procedure to prevent this risk, but some public discussion is needed first. So for the moment, just warn people against using `make check` when there are untrusted users on the same machine. (CVE-2014-0067)

- Fix possible mis-replay of WAL records when some segments of a relation aren't full size (Greg Stark, Tom Lane)

  The WAL update could be applied to the wrong page, potentially many pages past where it should have been. Aside from corrupting data, this error has been observed to result in significant "bloat" of standby servers compared to their masters, due to updates being applied far beyond where the end-of-file should have been. This failure mode does not appear to be a significant risk during crash recovery, only when initially synchronizing a standby created from a base backup taken from a quickly-changing master.

- Ensure that insertions into non-leaf GIN index pages write a full-page WAL record when appropriate (Heikki Linnakangas)

The previous coding risked index corruption in the event of a partial-page write during a system crash.

- Fix race conditions during server process exit (Robert Haas)

  Ensure that signal handlers don't attempt to use the process's `MyProc` pointer after it's no longer valid.

- Fix unsafe references to `errno` within error reporting logic (Christian Kruse)

  This would typically lead to odd behaviors such as missing or inappropriate `HINT` fields.

- Fix possible crashes from using `ereport()` too early during server startup (Tom Lane)

  The principal case we've seen in the field is a crash if the server is started in a directory it doesn't have permission to read.

- Clear retry flags properly in OpenSSL socket write function (Alexander Kukushkin)

  This omission could result in a server lockup after unexpected loss of an SSL-encrypted connection.

- Fix length checking for Unicode identifiers (`U&"..."` syntax) containing escapes (Tom Lane)

  A spurious truncation warning would be printed for such identifiers if the escaped form of the identifier was too long, but the identifier actually didn't need truncation after de-escaping.

- Fix possible crash due to invalid plan for nested sub-selects, such as `WHERE (... x IN (SELECT ...) ...) IN (SELECT ...)` (Tom Lane)

- Ensure that `ANALYZE` creates statistics for a table column even when all the values in it are "too wide" (Tom Lane)

  `ANALYZE` intentionally omits very wide values from its histogram and most-common-values calculations, but it neglected to do something sane in the case that all the sampled entries are too wide.

- In `ALTER TABLE ... SET TABLESPACE`, allow the database's default tablespace to be used without a permissions check (Stephen Frost)

  `CREATE TABLE` has always allowed such usage, but `ALTER TABLE` didn't get the memo.

- Fix "cannot accept a set" error when some arms of a `CASE` return a set and others don't (Tom Lane)

- Fix checks for all-zero client addresses in pgstat functions (Kevin Grittner)

- Fix possible misclassification of multibyte characters by the text search parser (Tom Lane)

  Non-ASCII characters could be misclassified when using C locale with a multibyte encoding. On Cygwin, non-C locales could fail as well.

- Fix possible misbehavior in `plainto_tsquery()` (Heikki Linnakangas)

  Use `memmove()` not `memcpy()` for copying overlapping memory regions. There have been no field reports of this actually causing trouble, but it's certainly risky.

- Accept `SHIFT_JIS` as an encoding name for locale checking purposes (Tatsuo Ishii)

- Fix misbehavior of `PQhost()` on Windows (Fujii Masao)

  It should return `localhost` if no host has been specified.

- Improve error handling in libpq and psql for failures during `COPY TO STDOUT/FROM STDIN` (Tom Lane)

  In particular this fixes an infinite loop that could occur in 9.2 and up if the server connection was lost during `COPY FROM STDIN`. Variants of that scenario might be possible in older versions, or with other client applications.

- Fix misaligned descriptors in ecpg (MauMau)
- In ecpg, handle lack of a hostname in the connection parameters properly (Michael Meskes)
- Fix performance regression in `contrib/dblink` connection startup (Joe Conway)

  Avoid an unnecessary round trip when client and server encodings match.
- In `contrib/isn`, fix incorrect calculation of the check digit for ISMN values (Fabien Coelho)
- Ensure client-code-only installation procedure works as documented (Peter Eisentraut)
- In Mingw and Cygwin builds, install the libpq DLL in the `bin` directory (Andrew Dunstan)

  This duplicates what the MSVC build has long done. It should fix problems with programs like psql failing to start because they can't find the DLL.
- Don't generate plain-text `HISTORY` and `src/test/regress/README` files anymore (Tom Lane)

  These text files duplicated the main HTML and PDF documentation formats. The trouble involved in maintaining them greatly outweighs the likely audience for plain-text format. Distribution tarballs will still contain files by these names, but they'll just be stubs directing the reader to consult the main documentation. The plain-text `INSTALL` file will still be maintained, as there is arguably a use-case for that.
- Update time zone data files to tzdata release 2013i for DST law changes in Jordan and historical changes in Cuba.

  In addition, the zones `Asia/Riyadh87`, `Asia/Riyadh88`, and `Asia/Riyadh89` have been removed, as they are no longer maintained by IANA, and never represented actual civil timekeeping practice.

E.60. Release 8.4.19

Release Date: 2013-12-05

This release contains a variety of fixes from 8.4.18. For information about new features in the 8.4 major release, see Section E.79.

E.60.1. Migration to Version 8.4.19

A dump/restore is not required for those running 8.4.X.

However, this release corrects a potential data corruption issue. See the first changelog entry below to find out whether your installation has been affected and what steps you can take if so.

Also, if you are upgrading from a version earlier than 8.4.17, see Section E.62.

E.60.2. Changes

- Fix `VACUUM`'s tests to see whether it can update `relfrozenxid` (Andres Freund)

In some cases `VACUUM` (either manual or autovacuum) could incorrectly advance a table's `relfrozenxid` value, allowing tuples to escape freezing, causing those rows to become invisible once 2^31 transactions have elapsed. The probability of data loss is fairly low since multiple incorrect advancements would need to happen before actual loss occurs, but it's not zero. Users upgrading from release 8.4.8 or earlier are not affected, but all later versions contain the bug.

The issue can be ameliorated by, after upgrading, vacuuming all tables in all databases while having `vacuum_freeze_table_age` set to zero. This will fix any latent corruption but will not be able to fix all pre-existing data errors. However, an installation can be presumed safe after performing this vacuuming if it has executed fewer than 2^31 update transactions in its lifetime (check this with `SELECT txid_current() < 2^31`).

- Fix race condition in GIN index posting tree page deletion (Heikki Linnakangas)

  This could lead to transient wrong answers or query failures.

- Avoid flattening a subquery whose `SELECT` list contains a volatile function wrapped inside a sub-`SELECT` (Tom Lane)

  This avoids unexpected results due to extra evaluations of the volatile function.

- Fix planner's processing of non-simple-variable subquery outputs nested within outer joins (Tom Lane)

  This error could lead to incorrect plans for queries involving multiple levels of subqueries within `JOIN` syntax.

- Fix premature deletion of temporary files (Andres Freund)

- Fix possible read past end of memory in rule printing (Peter Eisentraut)

- Fix array slicing of `int2vector` and `oidvector` values (Tom Lane)

  Expressions of this kind are now implicitly promoted to regular `int2` or `oid` arrays.

- Fix incorrect behaviors when using a SQL-standard, simple GMT offset timezone (Tom Lane)

  In some cases, the system would use the simple GMT offset value when it should have used the regular timezone setting that had prevailed before the simple offset was selected. This change also causes the `timeofday` function to honor the simple GMT offset zone.

- Prevent possible misbehavior when logging translations of Windows error codes (Tom Lane)

- Properly quote generated command lines in pg_ctl (Naoya Anzai and Tom Lane)

  This fix applies only to Windows.

- Fix pg_dumpall to work when a source database sets `default_transaction_read_only` via `ALTER DATABASE SET` (Kevin Grittner)

  Previously, the generated script would fail during restore.

- Fix ecpg's processing of lists of variables declared `varchar` (Zoltán Böszörményi)

- Make `contrib/lo` defend against incorrect trigger definitions (Marc Cousin)

- Update time zone data files to tzdata release 2013h for DST law changes in Argentina, Brazil, Jordan, Libya, Liechtenstein, Morocco, and Palestine. Also, new timezone abbreviations WIB, WIT, WITA for Indonesia.

E.61. Release 8.4.18

Release Date: 2013-10-10

This release contains a variety of fixes from 8.4.17. For information about new features in the 8.4 major release, see Section E.79.

E.61.1. Migration to Version 8.4.18

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.17, see Section E.62.

E.61.2. Changes

- Prevent corruption of multi-byte characters when attempting to case-fold identifiers (Andrew Dunstan)

  PostgreSQL case-folds non-ASCII characters only when using a single-byte server encoding.
- Fix memory leak caused by `lo_open()` failure (Heikki Linnakangas)
- Fix memory overcommit bug when `work_mem` is using more than 24GB of memory (Stephen Frost)
- Fix deadlock bug in libpq when using SSL (Stephen Frost)
- Properly compute row estimates for boolean columns containing many NULL values (Andrew Gierth)

  Previously tests like `col IS NOT TRUE` and `col IS NOT FALSE` did not properly factor in NULL values when estimating plan costs.
- Prevent pushing down `WHERE` clauses into unsafe `UNION/INTERSECT` subqueries (Tom Lane)

  Subqueries of a `UNION` or `INTERSECT` that contain set-returning functions or volatile functions in their `SELECT` lists could be improperly optimized, leading to run-time errors or incorrect query results.
- Fix rare case of "failed to locate grouping columns" planner failure (Tom Lane)
- Improve view dumping code's handling of dropped columns in referenced tables (Tom Lane)
- Fix possible deadlock during concurrent `CREATE INDEX CONCURRENTLY` operations (Tom Lane)
- Fix `regexp_matches()` handling of zero-length matches (Jeevan Chalke)

  Previously, zero-length matches like '^' could return too many matches.
- Fix crash for overly-complex regular expressions (Heikki Linnakangas)
- Fix regular expression match failures for back references combined with non-greedy quantifiers (Jeevan Chalke)
- Prevent `CREATE FUNCTION` from checking `SET` variables unless function body checking is enabled (Tom Lane)
- Fix `pgp_pub_decrypt()` so it works for secret keys with passwords (Marko Kreen)
- Remove rare inaccurate warning during vacuum of index-less tables (Heikki Linnakangas)

- Avoid possible failure when performing transaction control commands (e.g `ROLLBACK`) in prepared queries (Tom Lane)
- Ensure that floating-point data input accepts standard spellings of "infinity" on all platforms (Tom Lane)

  The C99 standard says that allowable spellings are `inf`, `+inf`, `-inf`, `infinity`, `+infinity`, and `-infinity`. Make sure we recognize these even if the platform's `strtod` function doesn't.
- Expand ability to compare rows to records and arrays (Rafal Rzepecki, Tom Lane)
- Update time zone data files to tzdata release 2013d for DST law changes in Israel, Morocco, Palestine, and Paraguay. Also, historical zone data corrections for Macquarie Island.

E.62. Release 8.4.17

Release Date: 2013-04-04

This release contains a variety of fixes from 8.4.16. For information about new features in the 8.4 major release, see Section E.79.

E.62.1. Migration to Version 8.4.17

A dump/restore is not required for those running 8.4.X.

However, this release corrects several errors in management of GiST indexes. After installing this update, it is advisable to `REINDEX` any GiST indexes that meet one or more of the conditions described below.

Also, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.62.2. Changes

- Reset OpenSSL randomness state in each postmaster child process (Marko Kreen)

  This avoids a scenario wherein random numbers generated by `contrib/pgcrypto` functions might be relatively easy for another database user to guess. The risk is only significant when the postmaster is configured with `ssl = on` but most connections don't use SSL encryption. (CVE-2013-1900)
- Fix GiST indexes to not use "fuzzy" geometric comparisons when it's not appropriate to do so (Alexander Korotkov)

  The core geometric types perform comparisons using "fuzzy" equality, but `gist_box_same` must do exact comparisons, else GiST indexes using it might become inconsistent. After installing this update, users should `REINDEX` any GiST indexes on `box`, `polygon`, `circle`, or `point` columns, since all of these use `gist_box_same`.
- Fix erroneous range-union and penalty logic in GiST indexes that use `contrib/btree_gist` for variable-width data types, that is `text`, `bytea`, `bit`, and `numeric` columns (Tom Lane)

These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in useless index bloat. Users are advised to `REINDEX` such indexes after installing this update.

- Fix bugs in GiST page splitting code for multi-column indexes (Tom Lane)

  These errors could result in inconsistent indexes in which some keys that are present would not be found by searches, and also in indexes that are unnecessarily inefficient to search. Users are advised to `REINDEX` multi-column GiST indexes after installing this update.

- Fix infinite-loop risk in regular expression compilation (Tom Lane, Don Porter)
- Fix potential null-pointer dereference in regular expression compilation (Tom Lane)
- Fix `to_char()` to use ASCII-only case-folding rules where appropriate (Tom Lane)

  This fixes misbehavior of some template patterns that should be locale-independent, but mishandled "`I`" and "`i`" in Turkish locales.

- Fix unwanted rejection of timestamp `1999-12-31 24:00:00` (Tom Lane)
- Remove useless "picksplit doesn't support secondary split" log messages (Josh Hansen, Tom Lane)

  This message seems to have been added in expectation of code that was never written, and probably never will be, since GiST's default handling of secondary splits is actually pretty good. So stop nagging end users about it.

- Fix possible failure to send a session's last few transaction commit/abort counts to the statistics collector (Tom Lane)
- Eliminate memory leaks in PL/Perl's `spi_prepare()` function (Alex Hunsaker, Tom Lane)
- Fix pg_dumpall to handle database names containing "=" correctly (Heikki Linnakangas)
- Avoid crash in pg_dump when an incorrect connection string is given (Heikki Linnakangas)
- Ignore invalid indexes in pg_dump (Michael Paquier)

  Dumping invalid indexes can cause problems at restore time, for example if the reason the index creation failed was because it tried to enforce a uniqueness condition not satisfied by the table's data. Also, if the index creation is in fact still in progress, it seems reasonable to consider it to be an uncommitted DDL change, which pg_dump wouldn't be expected to dump anyway.

- Fix `contrib/pg_trgm`'s `similarity()` function to return zero for trigram-less strings (Tom Lane)

  Previously it returned `NaN` due to internal division by zero.

- Update time zone data files to tzdata release 2013b for DST law changes in Chile, Haiti, Morocco, Paraguay, and some Russian areas. Also, historical zone data corrections for numerous places.

  Also, update the time zone abbreviation files for recent changes in Russia and elsewhere: `CHOT`, `GET`, `IRKT`, `KGT`, `KRAT`, `MAGT`, `MAWT`, `MSK`, `NOVT`, `OMST`, `TKT`, `VLAT`, `WST`, `YAKT`, `YEKT` now follow their current meanings, and `VOLT` (Europe/Volgograd) and `MIST` (Antarctica/Macquarie) are added to the default abbreviations list.

E.63. Release 8.4.16

Release Date: 2013-02-07

This release contains a variety of fixes from 8.4.15. For information about new features in the 8.4 major release, see Section E.79.

E.63.1. Migration to Version 8.4.16

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.63.2. Changes

- Prevent execution of `enum_recv` from SQL (Tom Lane)

  The function was misdeclared, allowing a simple SQL command to crash the server. In principle an attacker might be able to use it to examine the contents of server memory. Our thanks to Sumit Soni (via Secunia SVCRP) for reporting this issue. (CVE-2013-0255)

- Update minimum recovery point when truncating a relation file (Heikki Linnakangas)

  Once data has been discarded, it's no longer safe to stop recovery at an earlier point in the timeline.

- Fix SQL grammar to allow subscripting or field selection from a sub-SELECT result (Tom Lane)

- Protect against race conditions when scanning `pg_tablespace` (Stephen Frost, Tom Lane)

  `CREATE DATABASE` and `DROP DATABASE` could misbehave if there were concurrent updates of `pg_tablespace` entries.

- Prevent `DROP OWNED` from trying to drop whole databases or tablespaces (Álvaro Herrera)

  For safety, ownership of these objects must be reassigned, not dropped.

- Fix error in `vacuum_freeze_table_age` implementation (Andres Freund)

  In installations that have existed for more than `vacuum_freeze_min_age` transactions, this mistake prevented autovacuum from using partial-table scans, so that a full-table scan would always happen instead.

- Prevent misbehavior when a `RowExpr` or `XmlExpr` is parse-analyzed twice (Andres Freund, Tom Lane)

  This mistake could be user-visible in contexts such as `CREATE TABLE LIKE INCLUDING INDEXES`.

- Improve defenses against integer overflow in hashtable sizing calculations (Jeff Davis)

- Reject out-of-range dates in `to_date()` (Hitoshi Harada)

- Ensure that non-ASCII prompt strings are translated to the correct code page on Windows (Alexander Law, Noah Misch)

  This bug affected psql and some other client programs.

- Fix possible crash in psql's `\?` command when not connected to a database (Meng Qingzhong)

- Fix one-byte buffer overrun in libpq's `PQprintTuples` (Xi Wang)

  This ancient function is not used anywhere by PostgreSQL itself, but it might still be used by some client code.

- Make ecpglib use translated messages properly (Chen Huajun)

- Properly install ecpg_compat and pgtypes libraries on MSVC (Jiang Guiqing)
- Rearrange configure's tests for supplied functions so it is not fooled by bogus exports from libedit/libreadline (Christoph Berg)
- Ensure Windows build number increases over time (Magnus Hagander)
- Make pgxs build executables with the right `.exe` suffix when cross-compiling for Windows (Zoltan Boszormenyi)
- Add new timezone abbreviation `FET` (Tom Lane)

  This is now used in some eastern-European time zones.

E.64. Release 8.4.15

Release Date: 2012-12-06

This release contains a variety of fixes from 8.4.14. For information about new features in the 8.4 major release, see Section E.79.

E.64.1. Migration to Version 8.4.15

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.64.2. Changes

- Fix multiple bugs associated with `CREATE INDEX CONCURRENTLY` (Andres Freund, Tom Lane)

  Fix `CREATE INDEX CONCURRENTLY` to use in-place updates when changing the state of an index's `pg_index` row. This prevents race conditions that could cause concurrent sessions to miss updating the target index, thus resulting in corrupt concurrently-created indexes.

  Also, fix various other operations to ensure that they ignore invalid indexes resulting from a failed `CREATE INDEX CONCURRENTLY` command. The most important of these is `VACUUM`, because an auto-vacuum could easily be launched on the table before corrective action can be taken to fix or remove the invalid index.
- Avoid corruption of internal hash tables when out of memory (Hitoshi Harada)
- Fix planning of non-strict equivalence clauses above outer joins (Tom Lane)

  The planner could derive incorrect constraints from a clause equating a non-strict construct to something else, for example `WHERE COALESCE(foo, 0) = 0` when `foo` is coming from the nullable side of an outer join.
- Improve planner's ability to prove exclusion constraints from equivalence classes (Tom Lane)
- Fix partial-row matching in hashed subplans to handle cross-type cases correctly (Tom Lane)

This affects multicolumn `NOT IN` subplans, such as `WHERE (a, b) NOT IN (SELECT x, y FROM ...)` when for instance `b` and `y` are `int4` and `int8` respectively. This mistake led to wrong answers or crashes depending on the specific datatypes involved.

- Acquire buffer lock when re-fetching the old tuple for an `AFTER ROW UPDATE/DELETE` trigger (Andres Freund)

  In very unusual circumstances, this oversight could result in passing incorrect data to the precheck logic for a foreign-key enforcement trigger. That could result in a crash, or in an incorrect decision about whether to fire the trigger.

- Fix `ALTER COLUMN TYPE` to handle inherited check constraints properly (Pavan Deolasee)

  This worked correctly in pre-8.4 releases, and now works correctly in 8.4 and later.

- Fix `REASSIGN OWNED` to handle grants on tablespaces (Álvaro Herrera)

- Ignore incorrect `pg_attribute` entries for system columns for views (Tom Lane)

  Views do not have any system columns. However, we forgot to remove such entries when converting a table to a view. That's fixed properly for 9.3 and later, but in previous branches we need to defend against existing mis-converted views.

- Fix rule printing to dump `INSERT INTO` *`table`* `DEFAULT VALUES` correctly (Tom Lane)

- Guard against stack overflow when there are too many `UNION`/`INTERSECT`/`EXCEPT` clauses in a query (Tom Lane)

- Prevent platform-dependent failures when dividing the minimum possible integer value by -1 (Xi Wang, Tom Lane)

- Fix possible access past end of string in date parsing (Hitoshi Harada)

- Produce an understandable error message if the length of the path name for a Unix-domain socket exceeds the platform-specific limit (Tom Lane, Andrew Dunstan)

  Formerly, this would result in something quite unhelpful, such as "Non-recoverable failure in name resolution".

- Fix memory leaks when sending composite column values to the client (Tom Lane)

- Make pg_ctl more robust about reading the `postmaster.pid` file (Heikki Linnakangas)

  Fix race conditions and possible file descriptor leakage.

- Fix possible crash in psql if incorrectly-encoded data is presented and the `client_encoding` setting is a client-only encoding, such as SJIS (Jiang Guiqing)

- Fix bugs in the `restore.sql` script emitted by pg_dump in `tar` output format (Tom Lane)

  The script would fail outright on tables whose names include upper-case characters. Also, make the script capable of restoring data in `--inserts` mode as well as the regular COPY mode.

- Fix pg_restore to accept POSIX-conformant `tar` files (Brian Weaver, Tom Lane)

  The original coding of pg_dump's `tar` output mode produced files that are not fully conformant with the POSIX standard. This has been corrected for version 9.3. This patch updates previous branches so that they will accept both the incorrect and the corrected formats, in hopes of avoiding compatibility problems when 9.3 comes out.

- Fix pg_resetxlog to locate `postmaster.pid` correctly when given a relative path to the data directory (Tom Lane)

  This mistake could lead to pg_resetxlog not noticing that there is an active postmaster using the data directory.

- Fix libpq's `lo_import()` and `lo_export()` functions to report file I/O errors properly (Tom Lane)
- Fix ecpg's processing of nested structure pointer variables (Muhammad Usama)
- Make `contrib/pageinspect`'s btree page inspection functions take buffer locks while examining pages (Tom Lane)
- Fix pgxs support for building loadable modules on AIX (Tom Lane)

  Building modules outside the original source tree didn't work on AIX.
- Update time zone data files to tzdata release 2012j for DST law changes in Cuba, Israel, Jordan, Libya, Palestine, Western Samoa, and portions of Brazil.

E.65. Release 8.4.14

Release Date: 2012-09-24

This release contains a variety of fixes from 8.4.13. For information about new features in the 8.4 major release, see Section E.79.

E.65.1. Migration to Version 8.4.14

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.65.2. Changes

- Fix planner's assignment of executor parameters, and fix executor's rescan logic for CTE plan nodes (Tom Lane)

  These errors could result in wrong answers from queries that scan the same `WITH` subquery multiple times.
- Improve page-splitting decisions in GiST indexes (Alexander Korotkov, Robert Haas, Tom Lane)

  Multi-column GiST indexes might suffer unexpected bloat due to this error.
- Fix cascading privilege revoke to stop if privileges are still held (Tom Lane)

  If we revoke a grant option from some role *X*, but *X* still holds that option via a grant from someone else, we should not recursively revoke the corresponding privilege from role(s) *Y* that *X* had granted it to.
- Fix handling of `SIGFPE` when PL/Perl is in use (Andres Freund)

  Perl resets the process's `SIGFPE` handler to `SIG_IGN`, which could result in crashes later on. Restore the normal Postgres signal handler after initializing PL/Perl.
- Prevent PL/Perl from crashing if a recursive PL/Perl function is redefined while being executed (Tom Lane)

- Work around possible misoptimization in PL/Perl (Tom Lane)

  Some Linux distributions contain an incorrect version of `pthread.h` that results in incorrect compiled code in PL/Perl, leading to crashes if a PL/Perl function calls another one that throws an error.

- Update time zone data files to tzdata release 2012f for DST law changes in Fiji

E.66. Release 8.4.13

Release Date: 2012-08-17

This release contains a variety of fixes from 8.4.12. For information about new features in the 8.4 major release, see Section E.79.

E.66.1. Migration to Version 8.4.13

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.66.2. Changes

- Prevent access to external files/URLs via XML entity references (Noah Misch, Tom Lane)

  `xml_parse()` would attempt to fetch external files or URLs as needed to resolve DTD and entity references in an XML value, thus allowing unprivileged database users to attempt to fetch data with the privileges of the database server. While the external data wouldn't get returned directly to the user, portions of it could be exposed in error messages if the data didn't parse as valid XML; and in any case the mere ability to check existence of a file might be useful to an attacker. (CVE-2012-3489)

- Prevent access to external files/URLs via `contrib/xml2`'s `xslt_process()` (Peter Eisentraut)

  libxslt offers the ability to read and write both files and URLs through stylesheet commands, thus allowing unprivileged database users to both read and write data with the privileges of the database server. Disable that through proper use of libxslt's security options. (CVE-2012-3488)

  Also, remove `xslt_process()`'s ability to fetch documents and stylesheets from external files/URLs. While this was a documented "feature", it was long regarded as a bad idea. The fix for CVE-2012-3489 broke that capability, and rather than expend effort on trying to fix it, we're just going to summarily remove it.

- Prevent too-early recycling of btree index pages (Noah Misch)

  When we allowed read-only transactions to skip assigning XIDs, we introduced the possibility that a deleted btree page could be recycled while a read-only transaction was still in flight to it. This would result in incorrect index search results. The probability of such an error occurring in the field seems very low because of the timing requirements, but nonetheless it should be fixed.

- Fix crash-safety bug with newly-created-or-reset sequences (Tom Lane)

If `ALTER SEQUENCE` was executed on a freshly created or reset sequence, and then precisely one `nextval()` call was made on it, and then the server crashed, WAL replay would restore the sequence to a state in which it appeared that no `nextval()` had been done, thus allowing the first sequence value to be returned again by the next `nextval()` call. In particular this could manifest for `serial` columns, since creation of a serial column's sequence includes an `ALTER SEQUENCE OWNED BY` step.

- Ensure the `backup_label` file is fsync'd after `pg_start_backup()` (Dave Kerr)
- Back-patch 9.1 improvement to compress the fsync request queue (Robert Haas)

  This improves performance during checkpoints. The 9.1 change has now seen enough field testing to seem safe to back-patch.
- Only allow autovacuum to be auto-canceled by a directly blocked process (Tom Lane)

  The original coding could allow inconsistent behavior in some cases; in particular, an autovacuum could get canceled after less than `deadlock_timeout` grace period.
- Improve logging of autovacuum cancels (Robert Haas)
- Fix log collector so that `log_truncate_on_rotation` works during the very first log rotation after server start (Tom Lane)
- Fix `WITH` attached to a nested set operation (`UNION`/`INTERSECT`/`EXCEPT`) (Tom Lane)
- Ensure that a whole-row reference to a subquery doesn't include any extra `GROUP BY` or `ORDER BY` columns (Tom Lane)
- Disallow copying whole-row references in `CHECK` constraints and index definitions during `CREATE TABLE` (Tom Lane)

  This situation can arise in `CREATE TABLE` with `LIKE` or `INHERITS`. The copied whole-row variable was incorrectly labeled with the row type of the original table not the new one. Rejecting the case seems reasonable for `LIKE`, since the row types might well diverge later. For `INHERITS` we should ideally allow it, with an implicit coercion to the parent table's row type; but that will require more work than seems safe to back-patch.
- Fix memory leak in `ARRAY(SELECT ...)` subqueries (Heikki Linnakangas, Tom Lane)
- Fix extraction of common prefixes from regular expressions (Tom Lane)

  The code could get confused by quantified parenthesized subexpressions, such as `^(foo)?bar`. This would lead to incorrect index optimization of searches for such patterns.
- Fix bugs with parsing signed *hh*`:`*mm* and *hh*`:`*mm*`:`*ss* fields in `interval` constants (Amit Kapila, Tom Lane)
- Report errors properly in `contrib/xml2`'s `xslt_process()` (Tom Lane)
- Update time zone data files to tzdata release 2012e for DST law changes in Morocco and Tokelau

E.67. Release 8.4.12

Release Date: 2012-06-04

This release contains a variety of fixes from 8.4.11. For information about new features in the 8.4 major release, see Section E.79.

E.67.1. Migration to Version 8.4.12

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.67.2. Changes

- Fix incorrect password transformation in `contrib/pgcrypto`'s DES `crypt()` function (Solar Designer)

  If a password string contained the byte value `0x80`, the remainder of the password was ignored, causing the password to be much weaker than it appeared. With this fix, the rest of the string is properly included in the DES hash. Any stored password values that are affected by this bug will thus no longer match, so the stored values may need to be updated. (CVE-2012-2143)

- Ignore `SECURITY DEFINER` and `SET` attributes for a procedural language's call handler (Tom Lane)

  Applying such attributes to a call handler could crash the server. (CVE-2012-2655)

- Allow numeric timezone offsets in `timestamp` input to be up to 16 hours away from UTC (Tom Lane)

  Some historical time zones have offsets larger than 15 hours, the previous limit. This could result in dumped data values being rejected during reload.

- Fix timestamp conversion to cope when the given time is exactly the last DST transition time for the current timezone (Tom Lane)

  This oversight has been there a long time, but was not noticed previously because most DST-using zones are presumed to have an indefinite sequence of future DST transitions.

- Fix `text` to `name` and `char` to `name` casts to perform string truncation correctly in multibyte encodings (Karl Schnaitter)

- Fix memory copying bug in `to_tsquery()` (Heikki Linnakangas)

- Fix planner's handling of outer PlaceHolderVars within subqueries (Tom Lane)

  This bug concerns sub-SELECTs that reference variables coming from the nullable side of an outer join of the surrounding query. In 9.1, queries affected by this bug would fail with "ERROR: Upper-level PlaceHolderVar found where not expected". But in 9.0 and 8.4, you'd silently get possibly-wrong answers, since the value transmitted into the subquery wouldn't go to null when it should.

- Fix slow session startup when `pg_attribute` is very large (Tom Lane)

  If `pg_attribute` exceeds one-fourth of `shared_buffers`, cache rebuilding code that is sometimes needed during session start would trigger the synchronized-scan logic, causing it to take many times longer than normal. The problem was particularly acute if many new sessions were starting at once.

- Ensure sequential scans check for query cancel reasonably often (Merlin Moncure)

  A scan encountering many consecutive pages that contain no live tuples would not respond to interrupts meanwhile.

- Ensure the Windows implementation of `PGSemaphoreLock()` clears `ImmediateInterruptOK` before returning (Tom Lane)

This oversight meant that a query-cancel interrupt received later in the same query could be accepted at an unsafe time, with unpredictable but not good consequences.

- Show whole-row variables safely when printing views or rules (Abbas Butt, Tom Lane)

  Corner cases involving ambiguous names (that is, the name could be either a table or column name of the query) were printed in an ambiguous way, risking that the view or rule would be interpreted differently after dump and reload. Avoid the ambiguous case by attaching a no-op cast.

- Fix `COPY FROM` to properly handle null marker strings that correspond to invalid encoding (Tom Lane)

  A null marker string such as `E'\\0'` should work, and did work in the past, but the case got broken in 8.4.

- Ensure autovacuum worker processes perform stack depth checking properly (Heikki Linnakangas)

  Previously, infinite recursion in a function invoked by auto-`ANALYZE` could crash worker processes.

- Fix logging collector to not lose log coherency under high load (Andrew Dunstan)

  The collector previously could fail to reassemble large messages if it got too busy.

- Fix logging collector to ensure it will restart file rotation after receiving SIGHUP (Tom Lane)

- Fix WAL replay logic for GIN indexes to not fail if the index was subsequently dropped (Tom Lane)

- Fix memory leak in PL/pgSQL's `RETURN NEXT` command (Joe Conway)

- Fix PL/pgSQL's `GET DIAGNOSTICS` command when the target is the function's first variable (Tom Lane)

- Fix potential access off the end of memory in psql's expanded display (`\x`) mode (Peter Eisentraut)

- Fix several performance problems in pg_dump when the database contains many objects (Jeff Janes, Tom Lane)

  pg_dump could get very slow if the database contained many schemas, or if many objects are in dependency loops, or if there are many owned sequences.

- Fix `contrib/dblink`'s `dblink_exec()` to not leak temporary database connections upon error (Tom Lane)

- Fix `contrib/dblink` to report the correct connection name in error messages (Kyotaro Horiguchi)

- Update time zone data files to tzdata release 2012c for DST law changes in Antarctica, Armenia, Chile, Cuba, Falkland Islands, Gaza, Haiti, Hebron, Morocco, Syria, and Tokelau Islands; also historical corrections for Canada.

E.68. Release 8.4.11

Release Date: 2012-02-27

This release contains a variety of fixes from 8.4.10. For information about new features in the 8.4 major release, see Section E.79.

E.68.1. Migration to Version 8.4.11

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.10, see Section E.69.

E.68.2. Changes

- Require execute permission on the trigger function for `CREATE TRIGGER` (Robert Haas)

  This missing check could allow another user to execute a trigger function with forged input data, by installing it on a table he owns. This is only of significance for trigger functions marked `SECURITY DEFINER`, since otherwise trigger functions run as the table owner anyway. (CVE-2012-0866)

- Remove arbitrary limitation on length of common name in SSL certificates (Heikki Linnakangas)

  Both libpq and the server truncated the common name extracted from an SSL certificate at 32 bytes. Normally this would cause nothing worse than an unexpected verification failure, but there are some rather-implausible scenarios in which it might allow one certificate holder to impersonate another. The victim would have to have a common name exactly 32 bytes long, and the attacker would have to persuade a trusted CA to issue a certificate in which the common name has that string as a prefix. Impersonating a server would also require some additional exploit to redirect client connections. (CVE-2012-0867)

- Convert newlines to spaces in names written in pg_dump comments (Robert Haas)

  pg_dump was incautious about sanitizing object names that are emitted within SQL comments in its output script. A name containing a newline would at least render the script syntactically incorrect. Maliciously crafted object names could present a SQL injection risk when the script is reloaded. (CVE-2012-0868)

- Fix btree index corruption from insertions concurrent with vacuuming (Tom Lane)

  An index page split caused by an insertion could sometimes cause a concurrently-running `VACUUM` to miss removing index entries that it should remove. After the corresponding table rows are removed, the dangling index entries would cause errors (such as "could not read block N in file ...") or worse, silently wrong query results after unrelated rows are re-inserted at the now-free table locations. This bug has been present since release 8.2, but occurs so infrequently that it was not diagnosed until now. If you have reason to suspect that it has happened in your database, reindexing the affected index will fix things.

- Update per-column permissions, not only per-table permissions, when changing table owner (Tom Lane)

  Failure to do this meant that any previously granted column permissions were still shown as having been granted by the old owner. This meant that neither the new owner nor a superuser could revoke the now-untraceable-to-table-owner permissions.

- Allow non-existent values for some settings in `ALTER USER/DATABASE SET` (Heikki Linnakangas)

  Allow `default_text_search_config`, `default_tablespace`, and `temp_tablespaces` to be set to names that are not known. This is because they might be known in another database where the setting is intended to be used, or for the tablespace cases because the tablespace might not be created yet. The same issue was previously recognized for `search_path`, and these settings now act like that one.

- Avoid crashing when we have problems deleting table files post-commit (Tom Lane)

Dropping a table should lead to deleting the underlying disk files only after the transaction commits. In event of failure then (for instance, because of wrong file permissions) the code is supposed to just emit a warning message and go on, since it's too late to abort the transaction. This logic got broken as of release 8.4, causing such situations to result in a PANIC and an unrestartable database.

- Track the OID counter correctly during WAL replay, even when it wraps around (Tom Lane)

  Previously the OID counter would remain stuck at a high value until the system exited replay mode. The practical consequences of that are usually nil, but there are scenarios wherein a standby server that's been promoted to master might take a long time to advance the OID counter to a reasonable value once values are needed.

- Fix regular expression back-references with * attached (Tom Lane)

  Rather than enforcing an exact string match, the code would effectively accept any string that satisfies the pattern sub-expression referenced by the back-reference symbol.

  A similar problem still afflicts back-references that are embedded in a larger quantified expression, rather than being the immediate subject of the quantifier. This will be addressed in a future PostgreSQL release.

- Fix recently-introduced memory leak in processing of `inet`/`cidr` values (Heikki Linnakangas)

  A patch in the December 2011 releases of PostgreSQL caused memory leakage in these operations, which could be significant in scenarios such as building a btree index on such a column.

- Fix dangling pointer after `CREATE TABLE AS`/`SELECT INTO` in a SQL-language function (Tom Lane)

  In most cases this only led to an assertion failure in assert-enabled builds, but worse consequences seem possible.

- Avoid double close of file handle in syslogger on Windows (MauMau)

  Ordinarily this error was invisible, but it would cause an exception when running on a debug version of Windows.

- Fix I/O-conversion-related memory leaks in plpgsql (Andres Freund, Jan Urbanski, Tom Lane)

  Certain operations would leak memory until the end of the current function.

- Improve pg_dump's handling of inherited table columns (Tom Lane)

  pg_dump mishandled situations where a child column has a different default expression than its parent column. If the default is textually identical to the parent's default, but not actually the same (for instance, because of schema search path differences) it would not be recognized as different, so that after dump and restore the child would be allowed to inherit the parent's default. Child columns that are `NOT NULL` where their parent is not could also be restored subtly incorrectly.

- Fix pg_restore's direct-to-database mode for INSERT-style table data (Tom Lane)

  Direct-to-database restores from archive files made with `--inserts` or `--column-inserts` options fail when using pg_restore from a release dated September or December 2011, as a result of an oversight in a fix for another problem. The archive file itself is not at fault, and text-mode output is okay.

- Allow `AT` option in ecpg `DEALLOCATE` statements (Michael Meskes)

  The infrastructure to support this has been there for awhile, but through an oversight there was still an error check rejecting the case.

- Fix error in `contrib/intarray`'s `int[] & int[]` operator (Guillaume Lelarge)

If the smallest integer the two input arrays have in common is 1, and there are smaller values in either array, then 1 would be incorrectly omitted from the result.

- Fix error detection in `contrib/pgcrypto`'s `encrypt_iv()` and `decrypt_iv()` (Marko Kreen)

  These functions failed to report certain types of invalid-input errors, and would instead return random garbage values for incorrect input.

- Fix one-byte buffer overrun in `contrib/test_parser` (Paul Guyot)

  The code would try to read one more byte than it should, which would crash in corner cases. Since `contrib/test_parser` is only example code, this is not a security issue in itself, but bad example code is still bad.

- Use `__sync_lock_test_and_set()` for spinlocks on ARM, if available (Martin Pitt)

  This function replaces our previous use of the `SWPB` instruction, which is deprecated and not available on ARMv6 and later. Reports suggest that the old code doesn't fail in an obvious way on recent ARM boards, but simply doesn't interlock concurrent accesses, leading to bizarre failures in multiprocess operation.

- Use `-fexcess-precision=standard` option when building with gcc versions that accept it (Andrew Dunstan)

  This prevents assorted scenarios wherein recent versions of gcc will produce creative results.

- Allow use of threaded Python on FreeBSD (Chris Rees)

  Our configure script previously believed that this combination wouldn't work; but FreeBSD fixed the problem, so remove that error check.

E.69. Release 8.4.10

Release Date: 2011-12-05

This release contains a variety of fixes from 8.4.9. For information about new features in the 8.4 major release, see Section E.79.

E.69.1. Migration to Version 8.4.10

A dump/restore is not required for those running 8.4.X.

However, a longstanding error was discovered in the definition of the `information_schema.referential_constraints` view. If you rely on correct results from that view, you should replace its definition as explained in the first changelog item below.

Also, if you are upgrading from a version earlier than 8.4.8, see Section E.71.

E.69.2. Changes

- Fix bugs in `information_schema.referential_constraints` view (Tom Lane)

This view was being insufficiently careful about matching the foreign-key constraint to the depended-on primary or unique key constraint. That could result in failure to show a foreign key constraint at all, or showing it multiple times, or claiming that it depends on a different constraint than the one it really does.

Since the view definition is installed by initdb, merely upgrading will not fix the problem. If you need to fix this in an existing installation, you can (as a superuser) drop the `information_schema` schema then re-create it by sourcing *`SHAREDIR`*`/information_schema.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) This must be repeated in each database to be fixed.

- Fix incorrect replay of WAL records for GIN index updates (Tom Lane)

  This could result in transiently failing to find index entries after a crash, or on a hot-standby server. The problem would be repaired by the next `VACUUM` of the index, however.

- Fix TOAST-related data corruption during `CREATE TABLE dest AS SELECT * FROM src` or `INSERT INTO dest SELECT * FROM src` (Tom Lane)

  If a table has been modified by `ALTER TABLE ADD COLUMN`, attempts to copy its data verbatim to another table could produce corrupt results in certain corner cases. The problem can only manifest in this precise form in 8.4 and later, but we patched earlier versions as well in case there are other code paths that could trigger the same bug.

- Fix race condition during toast table access from stale syscache entries (Tom Lane)

  The typical symptom was transient errors like "missing chunk number 0 for toast value NNNNN in pg_toast_2619", where the cited toast table would always belong to a system catalog.

- Track dependencies of functions on items used in parameter default expressions (Tom Lane)

  Previously, a referenced object could be dropped without having dropped or modified the function, leading to misbehavior when the function was used. Note that merely installing this update will not fix the missing dependency entries; to do that, you'd need to `CREATE OR REPLACE` each such function afterwards. If you have functions whose defaults depend on non-built-in objects, doing so is recommended.

- Allow inlining of set-returning SQL functions with multiple OUT parameters (Tom Lane)

- Make `DatumGetInetP()` unpack inet datums that have a 1-byte header, and add a new macro, `DatumGetInetPP()`, that does not (Heikki Linnakangas)

  This change affects no core code, but might prevent crashes in add-on code that expects `DatumGetInetP()` to produce an unpacked datum as per usual convention.

- Improve locale support in `money` type's input and output (Tom Lane)

  Aside from not supporting all standard `lc_monetary` formatting options, the input and output functions were inconsistent, meaning there were locales in which dumped `money` values could not be re-read.

- Don't let `transform_null_equals` affect `CASE foo WHEN NULL ...` constructs (Heikki Linnakangas)

  `transform_null_equals` is only supposed to affect `foo = NULL` expressions written directly by the user, not equality checks generated internally by this form of `CASE`.

- Change foreign-key trigger creation order to better support self-referential foreign keys (Tom Lane)

  For a cascading foreign key that references its own table, a row update will fire both the `ON UPDATE` trigger and the `CHECK` trigger as one event. The `ON UPDATE` trigger must execute first, else the `CHECK` will check a non-final state of the row and possibly throw an inappropriate error. However, the firing order of these triggers is determined by their names, which generally

sort in creation order since the triggers have auto-generated names following the convention "RI_ConstraintTrigger_NNNN". A proper fix would require modifying that convention, which we will do in 9.2, but it seems risky to change it in existing releases. So this patch just changes the creation order of the triggers. Users encountering this type of error should drop and re-create the foreign key constraint to get its triggers into the right order.

- Avoid floating-point underflow while tracking buffer allocation rate (Greg Matthews)

  While harmless in itself, on certain platforms this would result in annoying kernel log messages.

- Preserve configuration file name and line number values when starting child processes under Windows (Tom Lane)

  Formerly, these would not be displayed correctly in the `pg_settings` view.

- Preserve blank lines within commands in psql's command history (Robert Haas)

  The former behavior could cause problems if an empty line was removed from within a string literal, for example.

- Fix pg_dump to dump user-defined casts between auto-generated types, such as table rowtypes (Tom Lane)

- Use the preferred version of xsubpp to build PL/Perl, not necessarily the operating system's main copy (David Wheeler and Alex Hunsaker)

- Fix incorrect coding in `contrib/dict_int` and `contrib/dict_xsyn` (Tom Lane)

  Some functions incorrectly assumed that memory returned by `palloc()` is guaranteed zeroed.

- Honor query cancel interrupts promptly in `pgstatindex()` (Robert Haas)

- Ensure VPATH builds properly install all server header files (Peter Eisentraut)

- Shorten file names reported in verbose error messages (Peter Eisentraut)

  Regular builds have always reported just the name of the C file containing the error message call, but VPATH builds formerly reported an absolute path name.

- Fix interpretation of Windows timezone names for Central America (Tom Lane)

  Map "Central America Standard Time" to `CST6`, not `CST6CDT`, because DST is generally not observed anywhere in Central America.

- Update time zone data files to tzdata release 2011n for DST law changes in Brazil, Cuba, Fiji, Palestine, Russia, and Samoa; also historical corrections for Alaska and British East Africa.

E.70. Release 8.4.9

Release Date: 2011-09-26

This release contains a variety of fixes from 8.4.8. For information about new features in the 8.4 major release, see Section E.79.

E.70.1. Migration to Version 8.4.9

A dump/restore is not required for those running 8.4.X.

However, if you are upgrading from a version earlier than 8.4.8, see Section E.71.

E.70.2. Changes

- Fix bugs in indexing of in-doubt HOT-updated tuples (Tom Lane)

  These bugs could result in index corruption after reindexing a system catalog. They are not believed to affect user indexes.

- Fix multiple bugs in GiST index page split processing (Heikki Linnakangas)

  The probability of occurrence was low, but these could lead to index corruption.

- Fix possible buffer overrun in `tsvector_concat()` (Tom Lane)

  The function could underestimate the amount of memory needed for its result, leading to server crashes.

- Fix crash in `xml_recv` when processing a "standalone" parameter (Tom Lane)

- Make `pg_options_to_table` return NULL for an option with no value (Tom Lane)

  Previously such cases would result in a server crash.

- Avoid possibly accessing off the end of memory in `ANALYZE` and in SJIS-2004 encoding conversion (Noah Misch)

  This fixes some very-low-probability server crash scenarios.

- Prevent intermittent hang in interactions of startup process with bgwriter process (Simon Riggs)

  This affected recovery in non-hot-standby cases.

- Fix race condition in relcache init file invalidation (Tom Lane)

  There was a window wherein a new backend process could read a stale init file but miss the inval messages that would tell it the data is stale. The result would be bizarre failures in catalog accesses, typically "could not read block 0 in file ..." later during startup.

- Fix memory leak at end of a GiST index scan (Tom Lane)

  Commands that perform many separate GiST index scans, such as verification of a new GiST-based exclusion constraint on a table already containing many rows, could transiently require large amounts of memory due to this leak.

- Fix incorrect memory accounting (leading to possible memory bloat) in tuplestores supporting holdable cursors and plpgsql's `RETURN NEXT` command (Tom Lane)

- Fix performance problem when constructing a large, lossy bitmap (Tom Lane)

- Fix join selectivity estimation for unique columns (Tom Lane)

  This fixes an erroneous planner heuristic that could lead to poor estimates of the result size of a join.

- Fix nested PlaceHolderVar expressions that appear only in sub-select target lists (Tom Lane)

  This mistake could result in outputs of an outer join incorrectly appearing as NULL.

- Allow nested `EXISTS` queries to be optimized properly (Tom Lane)

- Fix array- and path-creating functions to ensure padding bytes are zeroes (Tom Lane)

  This avoids some situations where the planner will think that semantically-equal constants are not equal, resulting in poor optimization.

- Fix `EXPLAIN` to handle gating Result nodes within inner-indexscan subplans (Tom Lane)

  The usual symptom of this oversight was "bogus varno" errors.

- Work around gcc 4.6.0 bug that breaks WAL replay (Tom Lane)

  This could lead to loss of committed transactions after a server crash.

- Fix dump bug for `VALUES` in a view (Tom Lane)

- Disallow `SELECT FOR UPDATE/SHARE` on sequences (Tom Lane)

  This operation doesn't work as expected and can lead to failures.

- Fix `VACUUM` so that it always updates `pg_class.reltuples`/`relpages` (Tom Lane)

  This fixes some scenarios where autovacuum could make increasingly poor decisions about when to vacuum tables.

- Defend against integer overflow when computing size of a hash table (Tom Lane)

- Fix cases where `CLUSTER` might attempt to access already-removed TOAST data (Tom Lane)

- Fix portability bugs in use of credentials control messages for "peer" authentication (Tom Lane)

- Fix SSPI login when multiple roundtrips are required (Ahmed Shinwari, Magnus Hagander)

  The typical symptom of this problem was "The function requested is not supported" errors during SSPI login.

- Throw an error if `pg_hba.conf` contains `hostssl` but SSL is disabled (Tom Lane)

  This was concluded to be more user-friendly than the previous behavior of silently ignoring such lines.

- Fix typo in `pg_srand48` seed initialization (Andres Freund)

  This led to failure to use all bits of the provided seed. This function is not used on most platforms (only those without `srandom`), and the potential security exposure from a less-random-than-expected seed seems minimal in any case.

- Avoid integer overflow when the sum of `LIMIT` and `OFFSET` values exceeds 2^63 (Heikki Linnakangas)

- Add overflow checks to `int4` and `int8` versions of `generate_series()` (Robert Haas)

- Fix trailing-zero removal in `to_char()` (Marti Raudsepp)

  In a format with `FM` and no digit positions after the decimal point, zeroes to the left of the decimal point could be removed incorrectly.

- Fix `pg_size_pretty()` to avoid overflow for inputs close to 2^63 (Tom Lane)

- Weaken plpgsql's check for typmod matching in record values (Tom Lane)

  An overly enthusiastic check could lead to discarding length modifiers that should have been kept.

- Correctly handle quotes in locale names during initdb (Heikki Linnakangas)

  The case can arise with some Windows locales, such as "People's Republic of China".

- Fix pg_upgrade to preserve toast tables' relfrozenxids during an upgrade from 8.3 (Bruce Momjian)

  Failure to do this could lead to `pg_clog` files being removed too soon after the upgrade.

- In pg_ctl, support silent mode for service registrations on Windows (MauMau)

- Fix psql's counting of script file line numbers during `COPY` from a different file (Tom Lane)

- Fix pg_restore's direct-to-database mode for `standard_conforming_strings` (Tom Lane)

pg_restore could emit incorrect commands when restoring directly to a database server from an archive file that had been made with `standard_conforming_strings` set to `on`.

- Be more user-friendly about unsupported cases for parallel pg_restore (Tom Lane)

  This change ensures that such cases are detected and reported before any restore actions have been taken.

- Fix write-past-buffer-end and memory leak in libpq's LDAP service lookup code (Albe Laurenz)
- In libpq, avoid failures when using nonblocking I/O and an SSL connection (Martin Pihlak, Tom Lane)
- Improve libpq's handling of failures during connection startup (Tom Lane)

  In particular, the response to a server report of `fork()` failure during SSL connection startup is now saner.

- Improve libpq's error reporting for SSL failures (Tom Lane)
- Fix `PQsetvalue()` to avoid possible crash when adding a new tuple to a `PGresult` originally obtained from a server query (Andrew Chernow)
- Make ecpglib write `double` values with 15 digits precision (Akira Kurosawa)
- In ecpglib, be sure `LC_NUMERIC` setting is restored after an error (Michael Meskes)
- Apply upstream fix for blowfish signed-character bug (CVE-2011-2483) (Tom Lane)

  `contrib/pg_crypto`'s blowfish encryption code could give wrong results on platforms where char is signed (which is most), leading to encrypted passwords being weaker than they should be.

- Fix memory leak in `contrib/seg` (Heikki Linnakangas)
- Fix `pgstatindex()` to give consistent results for empty indexes (Tom Lane)
- Allow building with perl 5.14 (Alex Hunsaker)
- Update configure script's method for probing existence of system functions (Tom Lane)

  The version of autoconf we used in 8.3 and 8.2 could be fooled by compilers that perform link-time optimization.

- Fix assorted issues with build and install file paths containing spaces (Tom Lane)
- Update time zone data files to tzdata release 2011i for DST law changes in Canada, Egypt, Russia, Samoa, and South Sudan.

E.71. Release 8.4.8

Release Date: 2011-04-18

This release contains a variety of fixes from 8.4.7. For information about new features in the 8.4 major release, see Section E.79.

E.71.1. Migration to Version 8.4.8

A dump/restore is not required for those running 8.4.X.

However, if your installation was upgraded from a previous major release by running pg_upgrade, you should take action to prevent possible data loss due to a now-fixed bug in pg_upgrade. The recommended solution is to run VACUUM FREEZE on all TOAST tables. More information is available at http://wiki.postgresql.org/wiki/20110408pg_upgrade_fix[4].

Also, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.71.2. Changes

- Fix pg_upgrade's handling of TOAST tables (Bruce Momjian)

  The pg_class.relfrozenxid value for TOAST tables was not correctly copied into the new installation during pg_upgrade. This could later result in pg_clog files being discarded while they were still needed to validate tuples in the TOAST tables, leading to "could not access status of transaction" failures.

  This error poses a significant risk of data loss for installations that have been upgraded with pg_upgrade. This patch corrects the problem for future uses of pg_upgrade, but does not in itself cure the issue in installations that have been processed with a buggy version of pg_upgrade.

- Suppress incorrect "PD_ALL_VISIBLE flag was incorrectly set" warning (Heikki Linnakangas)

  VACUUM would sometimes issue this warning in cases that are actually valid.

- Disallow including a composite type in itself (Tom Lane)

  This prevents scenarios wherein the server could recurse infinitely while processing the composite type. While there are some possible uses for such a structure, they don't seem compelling enough to justify the effort required to make sure it always works safely.

- Avoid potential deadlock during catalog cache initialization (Nikhil Sontakke)

  In some cases the cache loading code would acquire share lock on a system index before locking the index's catalog. This could deadlock against processes trying to acquire exclusive locks in the other, more standard order.

- Fix dangling-pointer problem in BEFORE ROW UPDATE trigger handling when there was a concurrent update to the target tuple (Tom Lane)

  This bug has been observed to result in intermittent "cannot extract system attribute from virtual tuple" failures while trying to do UPDATE RETURNING ctid. There is a very small probability of more serious errors, such as generating incorrect index entries for the updated tuple.

- Disallow DROP TABLE when there are pending deferred trigger events for the table (Tom Lane)

  Formerly the DROP would go through, leading to "could not open relation with OID nnn" errors when the triggers were eventually fired.

- Prevent crash triggered by constant-false WHERE conditions during GEQO optimization (Tom Lane)

- Improve planner's handling of semi-join and anti-join cases (Tom Lane)

- Fix selectivity estimation for text search to account for NULLs (Jesper Krogh)

- Improve PL/pgSQL's ability to handle row types with dropped columns (Pavel Stehule)

  This is a back-patch of fixes previously made in 9.0.

- Fix PL/Python memory leak involving array slices (Daniel Popowich)

4. http://wiki.postgresql.org/wiki/20110408pg_upgrade_fix

- Fix pg_restore to cope with long lines (over 1KB) in TOC files (Tom Lane)
- Put in more safeguards against crashing due to division-by-zero with overly enthusiastic compiler optimization (Aurelien Jarno)
- Support use of dlopen() in FreeBSD and OpenBSD on MIPS (Tom Lane)

  There was a hard-wired assumption that this system function was not available on MIPS hardware on these systems. Use a compile-time test instead, since more recent versions have it.
- Fix compilation failures on HP-UX (Heikki Linnakangas)
- Fix version-incompatibility problem with libintl on Windows (Hiroshi Inoue)
- Fix usage of xcopy in Windows build scripts to work correctly under Windows 7 (Andrew Dunstan)

  This affects the build scripts only, not installation or usage.
- Fix path separator used by pg_regress on Cygwin (Andrew Dunstan)
- Update time zone data files to tzdata release 2011f for DST law changes in Chile, Cuba, Falkland Islands, Morocco, Samoa, and Turkey; also historical corrections for South Australia, Alaska, and Hawaii.

E.72. Release 8.4.7

Release Date: 2011-01-31

This release contains a variety of fixes from 8.4.6. For information about new features in the 8.4 major release, see Section E.79.

E.72.1. Migration to Version 8.4.7

A dump/restore is not required for those running 8.4.X. However, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.72.2. Changes

- Avoid failures when `EXPLAIN` tries to display a simple-form `CASE` expression (Tom Lane)

  If the `CASE`'s test expression was a constant, the planner could simplify the `CASE` into a form that confused the expression-display code, resulting in "unexpected CASE WHEN clause" errors.
- Fix assignment to an array slice that is before the existing range of subscripts (Tom Lane)

  If there was a gap between the newly added subscripts and the first pre-existing subscript, the code miscalculated how many entries needed to be copied from the old array's null bitmap, potentially leading to data corruption or crash.
- Avoid unexpected conversion overflow in planner for very distant date values (Tom Lane)

  The `date` type supports a wider range of dates than can be represented by the `timestamp` types, but the planner assumed it could always convert a date to timestamp with impunity.

- Fix pg_restore's text output for large objects (BLOBs) when `standard_conforming_strings` is on (Tom Lane)

  Although restoring directly to a database worked correctly, string escaping was incorrect if pg_restore was asked for SQL text output and `standard_conforming_strings` had been enabled in the source database.

- Fix erroneous parsing of `tsquery` values containing `... & !(subexpression) | ...` (Tom Lane)

  Queries containing this combination of operators were not executed correctly. The same error existed in `contrib/intarray`'s `query_int` type and `contrib/ltree`'s `ltxtquery` type.

- Fix buffer overrun in `contrib/intarray`'s input function for the `query_int` type (Apple)

  This bug is a security risk since the function's return address could be overwritten. Thanks to Apple Inc's security team for reporting this issue and supplying the fix. (CVE-2010-4015)

- Fix bug in `contrib/seg`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `seg` column. If you have such an index, consider `REINDEX`ing it after installing this update. (This is identical to the bug that was fixed in `contrib/cube` in the previous update.)

E.73. Release 8.4.6

Release Date: 2010-12-16

This release contains a variety of fixes from 8.4.5. For information about new features in the 8.4 major release, see Section E.79.

E.73.1. Migration to Version 8.4.6

A dump/restore is not required for those running 8.4.X. However, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.73.2. Changes

- Force the default `wal_sync_method` to be `fdatasync` on Linux (Tom Lane, Marti Raudsepp)

  The default on Linux has actually been `fdatasync` for many years, but recent kernel changes caused PostgreSQL to choose `open_datasync` instead. This choice did not result in any performance improvement, and caused outright failures on certain filesystems, notably `ext4` with the `data=journal` mount option.

- Fix assorted bugs in WAL replay logic for GIN indexes (Tom Lane)

  This could result in "bad buffer id: 0" failures or corruption of index contents during replication.

- Fix recovery from base backup when the starting checkpoint WAL record is not in the same WAL segment as its redo point (Jeff Davis)

- Fix persistent slowdown of autovacuum workers when multiple workers remain active for a long time (Tom Lane)

  The effective `vacuum_cost_limit` for an autovacuum worker could drop to nearly zero if it processed enough tables, causing it to run extremely slowly.

- Add support for detecting register-stack overrun on `IA64` (Tom Lane)

  The `IA64` architecture has two hardware stacks. Full prevention of stack-overrun failures requires checking both.

- Add a check for stack overflow in `copyObject()` (Tom Lane)

  Certain code paths could crash due to stack overflow given a sufficiently complex query.

- Fix detection of page splits in temporary GiST indexes (Heikki Linnakangas)

  It is possible to have a "concurrent" page split in a temporary index, if for example there is an open cursor scanning the index when an insertion is done. GiST failed to detect this case and hence could deliver wrong results when execution of the cursor continued.

- Fix error checking during early connection processing (Tom Lane)

  The check for too many child processes was skipped in some cases, possibly leading to postmaster crash when attempting to add the new child process to fixed-size arrays.

- Improve efficiency of window functions (Tom Lane)

  Certain cases where a large number of tuples needed to be read in advance, but `work_mem` was large enough to allow them all to be held in memory, were unexpectedly slow. `percent_rank()`, `cume_dist()` and `ntile()` in particular were subject to this problem.

- Avoid memory leakage while `ANALYZE`'ing complex index expressions (Tom Lane)

- Ensure an index that uses a whole-row Var still depends on its table (Tom Lane)

  An index declared like `create index i on t (foo(t.*))` would not automatically get dropped when its table was dropped.

- Do not "inline" a SQL function with multiple `OUT` parameters (Tom Lane)

  This avoids a possible crash due to loss of information about the expected result rowtype.

- Behave correctly if `ORDER BY`, `LIMIT`, `FOR UPDATE`, or `WITH` is attached to the `VALUES` part of `INSERT ... VALUES` (Tom Lane)

- Fix constant-folding of `COALESCE()` expressions (Tom Lane)

  The planner would sometimes attempt to evaluate sub-expressions that in fact could never be reached, possibly leading to unexpected errors.

- Fix postmaster crash when connection acceptance (`accept()` or one of the calls made immediately after it) fails, and the postmaster was compiled with GSSAPI support (Alexander Chernikov)

- Fix missed unlink of temporary files when `log_temp_files` is active (Tom Lane)

  If an error occurred while attempting to emit the log message, the unlink was not done, resulting in accumulation of temp files.

- Add print functionality for `InhRelation` nodes (Tom Lane)

  This avoids a failure when `debug_print_parse` is enabled and certain types of query are executed.

- Fix incorrect calculation of distance from a point to a horizontal line segment (Tom Lane)

  This bug affected several different geometric distance-measurement operators.

- Fix incorrect calculation of transaction status in ecpg (Itagaki Takahiro)
- Fix PL/pgSQL's handling of "simple" expressions to not fail in recursion or error-recovery cases (Tom Lane)
- Fix PL/Python's handling of set-returning functions (Jan Urbanski)

  Attempts to call SPI functions within the iterator generating a set result would fail.
- Fix bug in `contrib/cube`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `cube` column. If you have such an index, consider `REINDEX`ing it after installing this update.
- Don't emit "identifier will be truncated" notices in `contrib/dblink` except when creating new connections (Itagaki Takahiro)
- Fix potential coredump on missing public key in `contrib/pgcrypto` (Marti Raudsepp)
- Fix memory leak in `contrib/xml2`'s XPath query functions (Tom Lane)
- Update time zone data files to tzdata release 2010o for DST law changes in Fiji and Samoa; also historical corrections for Hong Kong.

E.74. Release 8.4.5

Release Date: 2010-10-04

This release contains a variety of fixes from 8.4.4. For information about new features in the 8.4 major release, see Section E.79.

E.74.1. Migration to Version 8.4.5

A dump/restore is not required for those running 8.4.X. However, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.74.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)
- Treat exit code 128 (`ERROR_WAIT_NO_CHILDREN`) as non-fatal on Windows (Magnus Hagander)

  Under high load, Windows processes will sometimes fail at startup with this error code. Formerly the postmaster treated this as a panic condition and restarted the whole database, but that seems to be an overreaction.
- Fix incorrect placement of placeholder evaluation (Tom Lane)

  This bug could result in query outputs being non-null when they should be null, in cases where the inner side of an outer join is a sub-select with non-strict expressions in its output list.
- Fix possible duplicate scans of `UNION ALL` member relations (Tom Lane)
- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.
- Fix mishandling of whole-row Vars that reference a view or sub-select and appear within a nested sub-select (Tom Lane)
- Fix mishandling of cross-type `IN` comparisons (Tom Lane)

  This could result in failures if the planner tried to implement an `IN` join with a sort-then-unique-then-plain-join plan.
- Fix computation of `ANALYZE` statistics for `tsvector` columns (Jan Urbanski)

  The original coding could produce incorrect statistics, leading to poor plan choices later.
- Improve planner's estimate of memory used by `array_agg()`, `string_agg()`, and similar aggregate functions (Hitoshi Harada)

  The previous drastic underestimate could lead to out-of-memory failures due to inappropriate choice of a hash-aggregation plan.
- Fix failure to mark cached plans as transient (Tom Lane)

  If a plan is prepared while `CREATE INDEX CONCURRENTLY` is in progress for one of the referenced tables, it is supposed to be re-planned once the index is ready for use. This was not happening reliably.
- Reduce PANIC to ERROR in some occasionally-reported btree failure cases, and provide additional detail in the resulting error messages (Tom Lane)

  This should improve the system's robustness with corrupted indexes.
- Fix incorrect search logic for partial-match queries with GIN indexes (Tom Lane)

  Cases involving AND/OR combination of several GIN index conditions didn't always give the right answer, and were sometimes much slower than necessary.
- Prevent show_session_authorization() from crashing within autovacuum processes (Tom Lane)
- Defend against functions returning setof record where not all the returned rows are actually of the same rowtype (Tom Lane)

- Fix possible corruption of pending trigger event lists during subtransaction rollback (Tom Lane)

  This could lead to a crash or incorrect firing of triggers.

- Fix possible failure when hashing a pass-by-reference function result (Tao Ma, Tom Lane)

- Improve merge join's handling of NULLs in the join columns (Tom Lane)

  A merge join can now stop entirely upon reaching the first NULL, if the sort order is such that NULLs sort high.

- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

  This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.

- Avoid recursion while assigning XIDs to heavily-nested subtransactions (Andres Freund, Robert Haas)

  The original coding could result in a crash if there was limited stack space.

- Avoid holding open old WAL segments in the walwriter process (Magnus Hagander, Heikki Linnakangas)

  The previous coding would prevent removal of no-longer-needed segments.

- Fix `log_line_prefix`'s `%i` escape, which could produce junk early in backend startup (Tom Lane)

- Prevent misinterpretation of partially-specified relation options for TOAST tables (Itagaki Takahiro)

  In particular, `fillfactor` would be read as zero if any other reloption had been set for the table, leading to serious bloat.

- Fix inheritance count tracking in `ALTER TABLE ... ADD CONSTRAINT` (Robert Haas)

- Fix possible data corruption in `ALTER TABLE ... SET TABLESPACE` when archiving is enabled (Jeff Davis)

- Allow `CREATE DATABASE` and `ALTER DATABASE ... SET TABLESPACE` to be interrupted by query-cancel (Guillaume Lelarge)

- Improve `CREATE INDEX`'s checking of whether proposed index expressions are immutable (Tom Lane)

- Fix `REASSIGN OWNED` to handle operator classes and families (Asko Tiidumaa)

- Fix possible core dump when comparing two empty `tsquery` values (Tom Lane)

- Fix `LIKE`'s handling of patterns containing `%` followed by _ (Tom Lane)

  We've fixed this before, but there were still some incorrectly-handled cases.

- Re-allow input of Julian dates prior to 0001-01-01 AD (Tom Lane)

  Input such as `'J100000'::date` worked before 8.4, but was unintentionally broken by added error-checking.

- Fix PL/pgSQL to throw an error, not crash, if a cursor is closed within a `FOR` loop that is iterating over that cursor (Heikki Linnakangas)

- In PL/Python, defend against null pointer results from `PyCObject_AsVoidPtr` and `PyCObject_FromVoidPtr` (Peter Eisentraut)

- In libpq, fix full SSL certificate verification for the case where both `host` and `hostaddr` are specified (Tom Lane)
- Make psql recognize `DISCARD ALL` as a command that should not be encased in a transaction block in autocommit-off mode (Itagaki Takahiro)
- Fix some issues in pg_dump's handling of SQL/MED objects (Tom Lane)

  Notably, pg_dump would always fail if run by a non-superuser, which was not intended.
- Improve pg_dump and pg_restore's handling of non-seekable archive files (Tom Lane, Robert Haas)

  This is important for proper functioning of parallel restore.
- Improve parallel pg_restore's ability to cope with selective restore (`-L` option) (Tom Lane)

  The original code tended to fail if the `-L` file commanded a non-default restore ordering.
- Fix ecpg to process data from `RETURNING` clauses correctly (Michael Meskes)
- Fix some memory leaks in ecpg (Zoltan Boszormenyi)
- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)
- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)
- Fix `contrib/dblink` to handle connection names longer than 62 bytes correctly (Itagaki Takahiro)
- Add `hstore(text, text)` function to `contrib/hstore` (Robert Haas)

  This function is the recommended substitute for the now-deprecated => operator. It was backpatched so that future-proofed code can be used with older server versions. Note that the patch will be effective only after `contrib/hstore` is installed or reinstalled in a particular database. Users might prefer to execute the `CREATE FUNCTION` command by hand, instead.
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)
- Update time zone data files to tzdata release 2010l for DST law changes in Egypt and Palestine; also historical corrections for Finland.

  This change also adds new names for two Micronesian timezones: Pacific/Chuuk is now preferred over Pacific/Truk (and the preferred abbreviation is CHUT not TRUT) and Pacific/Pohnpei is preferred over Pacific/Ponape.
- Make Windows' "N. Central Asia Standard Time" timezone map to Asia/Novosibirsk, not Asia/Almaty (Magnus Hagander)

  Microsoft changed the DST behavior of this zone in the timezone update from KB976098. Asia/Novosibirsk is a better match to its new behavior.

E.75. Release 8.4.4

Release Date: 2010-05-17

This release contains a variety of fixes from 8.4.3. For information about new features in the 8.4 major release, see Section E.79.

E.75.1. Migration to Version 8.4.4

A dump/restore is not required for those running 8.4.X. However, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.75.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b` variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Fix data corruption during WAL replay of `ALTER ... SET TABLESPACE` (Tom)

  When `archive_mode` is on, `ALTER ... SET TABLESPACE` generates a WAL record whose replay logic was incorrect. It could write the data to the wrong place, leading to possibly-unrecoverable data corruption. Data corruption would be observed on standby slaves, and could occur on the master as well if a database crash and recovery occurred after committing the `ALTER` and before the next checkpoint.

- Fix possible crash if a cache reset message is received during rebuild of a relcache entry (Heikki)

  This error was introduced in 8.4.3 while fixing a related failure.

- Apply per-function GUC settings while running the language validator for the function (Itagaki Takahiro)

  This avoids failures if the function's code is invalid without the setting; an example is that SQL functions may not parse if the `search_path` is not correct.

- Do constraint exclusion for inherited `UPDATE` and `DELETE` target tables when `constraint_exclusion` = `partition` (Tom)

  Due to an oversight, this setting previously only caused constraint exclusion to be checked in `SELECT` commands.

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

  In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Fix erroneous handling of `%r` parameter in `recovery_end_command` (Heikki)

  The value always came out zero.

- Ensure the archiver process responds to changes in `archive_command` as soon as possible (Tom)
- Fix pl/pgsql's `CASE` statement to not fail when the case expression is a query that returns no rows (Tom)
- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)
- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)
- Handle empty-string connect parameters properly in ecpg (Michael)
- Prevent infinite recursion in psql when expanding a variable that refers to itself (Tom)
- Fix psql's `\copy` to not add spaces around a dot within `\copy (select ...)` (Tom)

  Addition of spaces around the decimal point in a numeric literal would result in a syntax error.

- Avoid formatting failure in psql when running in a locale context that doesn't match the `client_encoding` (Tom)
- Fix unnecessary "GIN indexes do not support whole-index scans" errors for unsatisfiable queries using `contrib/intarray` operators (Tom)
- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)
- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.

- Avoid possible crashes in syslogger process on Windows (Heikki)
- Deal more robustly with incomplete time zone information in the Windows registry (Magnus)
- Update the set of known Windows time zone names (Magnus)
- Update time zone data files to tzdata release 2010j for DST law changes in Argentina, Australian Antarctic, Bangladesh, Mexico, Morocco, Pakistan, Palestine, Russia, Syria, Tunisia; also historical corrections for Taiwan.

  Also, add `PKST` (Pakistan Summer Time) to the default set of timezone abbreviations.

E.76. Release 8.4.3

Release Date: 2010-03-15

This release contains a variety of fixes from 8.4.2. For information about new features in the 8.4 major release, see Section E.79.

E.76.1. Migration to Version 8.4.3

A dump/restore is not required for those running 8.4.X. However, if you are upgrading from a version earlier than 8.4.2, see Section E.77.

E.76.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.
- Fix possible deadlock during backend startup (Tom)
- Fix possible crashes due to not handling errors during relcache reload cleanly (Tom)
- Fix possible crash due to use of dangling pointer to a cached plan (Tatsuo)
- Fix possible crash due to overenthusiastic invalidation of cached plan for `ROLLBACK` (Tom)
- Fix possible crashes when trying to recover from a failure in subtransaction start (Tom)
- Fix server memory leak associated with use of savepoints and a client encoding different from server's encoding (Tom)
- Fix incorrect WAL data emitted during end-of-recovery cleanup of a GIST index page split (Yoichi Hirai)

  This would result in index corruption, or even more likely an error during WAL replay, if we were unlucky enough to crash during end-of-recovery cleanup after having completed an incomplete GIST insertion.
- Fix bug in WAL redo cleanup method for GIN indexes (Heikki)
- Fix incorrect comparison of scan key in GIN index search (Teodor)
- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).
- Fix integer-to-bit-string conversions to handle the first fractional byte correctly when the output bit width is wider than the given integer by something other than a multiple of 8 bits (Tom)
- Fix some cases of pathologically slow regular expression matching (Tom)
- Fix bug occurring when trying to inline a SQL function that returns a set of a composite type that contains dropped columns (Tom)
- Fix bug with trying to update a field of an element of a composite-type array column (Tom)
- Avoid failure when `EXPLAIN` has to print a FieldStore or assignment ArrayRef expression (Tom)

These cases can arise now that `EXPLAIN VERBOSE` tries to print plan node target lists.

- Avoid an unnecessary coercion failure in some cases where an undecorated literal string appears in a subquery within `UNION`/`INTERSECT`/`EXCEPT` (Tom)

  This fixes a regression for some cases that worked before 8.4.

- Avoid undesirable rowtype compatibility check failures in some cases where a whole-row Var has a rowtype that contains dropped columns (Tom)

- Fix the `STOP WAL LOCATION` entry in backup history files to report the next WAL segment's name when the end location is exactly at a segment boundary (Itagaki Takahiro)

- Always pass the catalog ID to an option validator function specified in `CREATE FOREIGN DATA WRAPPER` (Martin Pihlak)

- Fix some more cases of temporary-file leakage (Heikki)

  This corrects a problem introduced in the previous minor release. One case that failed is when a plpgsql function returning set is called within another function's exception handler.

- Add support for doing `FULL JOIN ON FALSE` (Tom)

  This prevents a regression from pre-8.4 releases for some queries that can now be simplified to a constant-false join condition.

- Improve constraint exclusion processing of boolean-variable cases, in particular make it possible to exclude a partition that has a "bool_column = false" constraint (Tom)

- Prevent treating an `INOUT` cast as representing binary compatibility (Heikki)

- Include column name in the message when warning about inability to grant or revoke column-level privileges (Stephen Frost)

  This is more useful than before and helps to prevent confusion when a `REVOKE` generates multiple messages, which formerly appeared to be duplicates.

- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.

- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)

- Fix possible infinite loop if `SSL_read` or `SSL_write` fails without setting `errno` (Tom)

  This is reportedly possible with some Windows versions of openssl.

- Disallow GSSAPI authentication on local connections, since it requires a hostname to function correctly (Magnus)

- Protect ecpg against applications freeing strings unexpectedly (Michael)

- Make ecpg report the proper SQLSTATE if the connection disappears (Michael)

- Fix translation of cell contents in psql `\d` output (Heikki)

- Fix psql's `numericlocale` option to not format strings it shouldn't in latex and troff output formats (Heikki)

- Fix a small per-query memory leak in psql (Tom)

- Make psql return the correct exit status (3) when `ON_ERROR_STOP` and `--single-transaction` are both specified and an error occurs during the implied `COMMIT` (Bruce)

- Fix pg_dump's output of permissions for foreign servers (Heikki)
- Fix possible crash in parallel pg_restore due to out-of-range dependency IDs (Tom)
- Fix plpgsql failure in one case where a composite column is set to NULL (Tom)
- Fix possible failure when calling PL/Perl functions from PL/PerlU or vice versa (Tim Bunce)
- Add `volatile` markings in PL/Python to avoid possible compiler-specific misbehavior (Zdenek Kotala)
- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

  The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.
- Prevent `ExecutorEnd` from being run on portals created within a failed transaction or subtransaction (Tom)

  This is known to cause issues when using `contrib/auto_explain`.
- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)
- Allow zero-dimensional arrays in `contrib/ltree` operations (Tom)

  This case was formerly rejected as an error, but it's more convenient to treat it the same as a zero-element array. In particular this avoids unnecessary failures when an `ltree` operation is applied to the result of `ARRAY(SELECT ...)` and the sub-select returns no rows.
- Fix assorted crashes in `contrib/xml2` caused by sloppy memory management (Tom)
- Make building of `contrib/xml2` more robust on Windows (Andrew)
- Fix race condition in Windows signal handling (Radu Ilie)

  One known symptom of this bug is that rows in `pg_listener` could be dropped under heavy load.
- Make the configure script report failure if the C compiler does not provide a working 64-bit integer datatype (Tom)

  This case has been broken for some time, and no longer seems worth supporting, so just reject it at configure time instead.
- Update time zone data files to tzdata release 2010e for DST law changes in Bangladesh, Chile, Fiji, Mexico, Paraguay, Samoa.

E.77. Release 8.4.2

Release Date: 2009-12-14

This release contains a variety of fixes from 8.4.1. For information about new features in the 8.4 major release, see Section E.79.

E.77.1. Migration to Version 8.4.2

A dump/restore is not required for those running 8.4.X. However, if you have any hash indexes, you should `REINDEX` them after updating to 8.4.2, to repair possible damage.

E.77.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).

- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).

- Fix hash index corruption (Tom)

  The 8.4 change that made hash indexes keep entries sorted by hash value failed to update the bucket splitting and compaction routines to preserve the ordering. So application of either of those operations could lead to permanent corruption of an index, in the sense that searches might fail to find entries that are present. To deal with this, it is recommended to `REINDEX` any hash indexes you may have after installing this update.

- Fix possible crash during backend-startup-time cache initialization (Tom)

- Avoid crash on empty thesaurus dictionary (Tom)

- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.

- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.

- Fix crash if a `DROP` is attempted on an internally-dependent object (Tom)

- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)

- Ensure that shared tuple-level locks held by prepared transactions are not ignored (Heikki)

- Fix premature drop of temporary files used for a cursor that is accessed within a subtransaction (Heikki)

- Fix memory leak in syslogger process when rotating to a new CSV logfile (Tom)

- Fix memory leak in postmaster when re-parsing `pg_hba.conf` (Tom)

- Fix Windows permission-downgrade logic (Jesse Morris)

  This fixes some cases where the database failed to start on Windows, often with misleading error messages such as "could not locate matching postgres executable".

- Make `FOR UPDATE/SHARE` in the primary query not propagate into `WITH` queries (Tom)

  For example, in

  ```
  WITH w AS (SELECT * FROM foo) SELECT * FROM w, bar ... FOR UPDATE
  ```

  the `FOR UPDATE` will now affect `bar` but not `foo`. This is more useful and consistent than the original 8.4 behavior, which tried to propagate `FOR UPDATE` into the `WITH` query but always failed due to assorted implementation restrictions. It also follows the design rule that `WITH` queries are executed as if independent of the main query.

- Fix bug with a `WITH RECURSIVE` query immediately inside another one (Tom)

- Fix concurrency bug in hash indexes (Tom)

Concurrent insertions could cause index scans to transiently report wrong results.

- Fix incorrect logic for GiST index page splits, when the split depends on a non-first column of the index (Paul Ramsey)
- Fix wrong search results for a multi-column GIN index with `fastupdate` enabled (Teodor)
- Fix bugs in WAL entry creation for GIN indexes (Tom)

  These bugs were masked when `full_page_writes` was on, but with it off a WAL replay failure was certain if a crash occurred before the next checkpoint.
- Don't error out if recycling or removing an old WAL file fails at the end of checkpoint (Heikki)

  It's better to treat the problem as non-fatal and allow the checkpoint to complete. Future checkpoints will retry the removal. Such problems are not expected in normal operation, but have been seen to be caused by misdesigned Windows anti-virus and backup software.
- Ensure WAL files aren't repeatedly archived on Windows (Heikki)

  This is another symptom that could happen if some other process interfered with deletion of a no-longer-needed file.
- Fix PAM password processing to be more robust (Tom)

  The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.
- Raise the maximum authentication token (Kerberos ticket) size in GSSAPI and SSPI authentication methods (Ian Turner)

  While the old 2000-byte limit was more than enough for Unix Kerberos implementations, tickets issued by Windows Domain Controllers can be much larger.
- Ensure that domain constraints are enforced in constructs like `ARRAY[...]::domain`, where the domain is over an array type (Heikki)
- Fix foreign-key logic for some cases involving composite-type columns as foreign keys (Tom)
- Ensure that a cursor's snapshot is not modified after it is created (Alvaro)

  This could lead to a cursor delivering wrong results if later operations in the same transaction modify the data the cursor is supposed to return.
- Fix `CREATE TABLE` to properly merge default expressions coming from different inheritance parent tables (Tom)

  This used to work but was broken in 8.4.
- Re-enable collection of access statistics for sequences (Akira Kurosawa)

  This used to work but was broken in 8.3.
- Fix processing of ownership dependencies during `CREATE OR REPLACE FUNCTION` (Tom)
- Fix incorrect handling of `WHERE x=x` conditions (Tom)

  In some cases these could get ignored as redundant, but they aren't — they're equivalent to `x IS NOT NULL`.
- Fix incorrect plan construction when using hash aggregation to implement `DISTINCT` for textually identical volatile expressions (Tom)
- Fix Assert failure for a volatile `SELECT DISTINCT ON` expression (Tom)
- Fix `ts_stat()` to not fail on an empty `tsvector` value (Tom)

- Make text search parser accept underscores in XML attributes (Peter)
- Fix encoding handling in `xml` binary input (Heikki)

  If the XML header doesn't specify an encoding, we now assume UTF-8 by default; the previous handling was inconsistent.
- Fix bug with calling `plperl` from `plperlu` or vice versa (Tom)

  An error exit from the inner function could result in crashes due to failure to re-select the correct Perl interpreter for the outer function.
- Fix session-lifespan memory leak when a PL/Perl function is redefined (Tom)
- Ensure that Perl arrays are properly converted to PostgreSQL arrays when returned by a set-returning PL/Perl function (Andrew Dunstan, Abhijit Menon-Sen)

  This worked correctly already for non-set-returning functions.
- Fix rare crash in exception processing in PL/Python (Peter)
- Fix ecpg problem with comments in `DECLARE CURSOR` statements (Michael)
- Fix ecpg to not treat recently-added keywords as reserved words (Tom)

  This affected the keywords `CALLED`, `CATALOG`, `DEFINER`, `ENUM`, `FOLLOWING`, `INVOKER`, `OPTIONS`, `PARTITION`, `PRECEDING`, `RANGE`, `SECURITY`, `SERVER`, `UNBOUNDED`, and `WRAPPER`.
- Re-allow regular expression special characters in psql's `\df` function name parameter (Tom)
- In `contrib/fuzzystrmatch`, correct the calculation of `levenshtein` distances with non-default costs (Marcin Mank)
- In `contrib/pg_standby`, disable triggering failover with a signal on Windows (Fujii Masao)

  This never did anything useful, because Windows doesn't have Unix-style signals, but recent changes made it actually crash.
- Put `FREEZE` and `VERBOSE` options in the right order in the `VACUUM` command that `contrib/vacuumdb` produces (Heikki)
- Fix possible leak of connections when `contrib/dblink` encounters an error (Tatsuhito Kasahara)
- Ensure psql's flex module is compiled with the correct system header definitions (Tom)

  This fixes build failures on platforms where `--enable-largefile` causes incompatible changes in the generated code.
- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)
- Update the timezone abbreviation files to match current reality (Joachim Wieland)

  This includes adding `IDT` to the default timezone abbreviation set.
- Update time zone data files to tzdata release 2009s for DST law changes in Antarctica, Argentina, Bangladesh, Fiji, Novokuznetsk, Pakistan, Palestine, Samoa, Syria; also historical corrections for Hong Kong.

E.78. Release 8.4.1

Release Date: 2009-09-09

This release contains a variety of fixes from 8.4. For information about new features in the 8.4 major release, see Section E.79.

E.78.1. Migration to Version 8.4.1

A dump/restore is not required for those running 8.4.X.

E.78.2. Changes

- Fix WAL page header initialization at the end of archive recovery (Heikki)

  This could lead to failure to process the WAL in a subsequent archive recovery.

- Fix "cannot make new WAL entries during recovery" error (Tom)

- Fix problem that could make expired rows visible after a crash (Tom)

  This bug involved a page status bit potentially not being set correctly after a server crash.

- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

  This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)

- Make `LOAD` of an already-loaded loadable module into a no-op (Tom)

  Formerly, `LOAD` would attempt to unload and re-load the module, but this is unsafe and not all that useful.

- Make window function `PARTITION BY` and `ORDER BY` items always be interpreted as simple expressions (Tom)

  In 8.4.0 these lists were parsed following the rules used for top-level `GROUP BY` and `ORDER BY` lists. But this was not correct per the SQL standard, and it led to possible circularity.

- Fix several errors in planning of semi-joins (Tom)

  These led to wrong query results in some cases where `IN` or `EXISTS` was used together with another join.

- Fix handling of whole-row references to subqueries that are within an outer join (Tom)

  An example is `SELECT COUNT(ss.*) FROM ... LEFT JOIN (SELECT ...) ss ON ...`. Here, `ss.*` would be treated as `ROW(NULL,NULL,...)` for null-extended join rows, which is not the same as a simple NULL. Now it is treated as a simple NULL.

- Fix Windows shared-memory allocation code (Tsutomu Yamada, Magnus)

  This bug led to the often-reported "could not reattach to shared memory" error message.

- Fix locale handling with plperl (Heikki)

  This bug could cause the server's locale setting to change when a plperl function is called, leading to data corruption.

- Fix handling of reloptions to ensure setting one option doesn't force default values for others (Itagaki Takahiro)

- Ensure that a "fast shutdown" request will forcibly terminate open sessions, even if a "smart shutdown" was already in progress (Fujii Masao)
- Avoid memory leak for `array_agg()` in `GROUP BY` queries (Tom)
- Treat `to_char(..., 'TH')` as an uppercase ordinal suffix with `'HH'`/`'HH12'` (Heikki)

  It was previously handled as `'th'` (lowercase).
- Include the fractional part in the result of `EXTRACT(second)` and `EXTRACT(milliseconds)` for `time` and `time with time zone` inputs (Tom)

  This has always worked for floating-point datetime configurations, but was broken in the integer datetime code.
- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Improve performance when processing toasted values in index scans (Tom)

  This is particularly useful for PostGIS[5].
- Fix a typo that disabled `commit_delay` (Jeff Janes)
- Output early-startup messages to `postmaster.log` if the server is started in silent mode (Tom)

  Previously such error messages were discarded, leading to difficulty in debugging.
- Remove translated FAQs (Peter)

  They are now on the wiki[6]. The main FAQ was moved to the wiki some time ago.
- Fix pg_ctl to not go into an infinite loop if `postgresql.conf` is empty (Jeff Davis)
- Fix several errors in pg_dump's `--binary-upgrade` mode (Bruce, Tom)

  `pg_dump --binary-upgrade` is used by pg_migrator.
- Fix `contrib/xml2`'s `xslt_process()` to properly handle the maximum number of parameters (twenty) (Tom)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)
- Work around gcc bug that causes "floating-point exception" instead of "division by zero" on some platforms (Tom)
- Update time zone data files to tzdata release 2009l for DST law changes in Bangladesh, Egypt, Mauritius.

E.79. Release 8.4

Release Date: 2009-07-01

5. http://postgis.refractions.net/
6. http://wiki.postgresql.org/wiki/FAQ

E.79.1. Overview

After many years of development, PostgreSQL has become feature-complete in many areas. This release shows a targeted approach to adding features (e.g., authentication, monitoring, space reuse), and adds capabilities defined in the later SQL standards. The major areas of enhancement are:

- Windowing Functions
- Common Table Expressions and Recursive Queries
- Default and variadic parameters for functions
- Parallel Restore
- Column Permissions
- Per-database locale settings
- Improved hash indexes
- Improved join performance for `EXISTS` and `NOT EXISTS` queries
- Easier-to-use Warm Standby
- Automatic sizing of the Free Space Map
- Visibility Map (greatly reduces vacuum overhead for slowly-changing tables)
- Version-aware psql (backslash commands work against older servers)
- Support SSL certificates for user authentication
- Per-function runtime statistics
- Easy editing of functions in psql
- New contrib modules: pg_stat_statements, auto_explain, citext, btree_gin

The above items are explained in more detail in the sections below.

E.79.2. Migration to Version 8.4

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

E.79.2.1. General

- Use 64-bit integer datetimes by default (Neil Conway)

  Previously this was selected by configure's `--enable-integer-datetimes` option. To retain the old behavior, build with `--disable-integer-datetimes`.

- Remove ipcclean utility command (Bruce)

  The utility only worked on a few platforms. Users should use their operating system tools instead.

E.79.2.2. Server Settings

- Change default setting for `log_min_messages` to `warning` (previously it was `notice`) to reduce log file volume (Tom)
- Change default setting for `max_prepared_transactions` to zero (previously it was 5) (Tom)
- Make `debug_print_parse`, `debug_print_rewritten`, and `debug_print_plan` output appear at `LOG` message level, not `DEBUG1` as formerly (Tom)
- Make `debug_pretty_print` default to `on` (Tom)
- Remove `explain_pretty_print` parameter (no longer needed) (Tom)
- Make `log_temp_files` settable by superusers only, like other logging options (Simon Riggs)
- Remove automatic appending of the epoch timestamp when no `%` escapes are present in `log_filename` (Robert Haas)

  This change was made because some users wanted a fixed log filename, for use with an external log rotation tool.
- Remove `log_restartpoints` from `recovery.conf`; instead use `log_checkpoints` (Simon)
- Remove `krb_realm` and `krb_server_hostname`; these are now set in `pg_hba.conf` instead (Magnus)
- There are also significant changes in `pg_hba.conf`, as described below.

E.79.2.3. Queries

- Change `TRUNCATE` and `LOCK` to apply to child tables of the specified table(s) (Peter)

  These commands now accept an `ONLY` option that prevents processing child tables; this option must be used if the old behavior is needed.
- `SELECT DISTINCT` and `UNION`/`INTERSECT`/`EXCEPT` no longer always produce sorted output (Tom)

  Previously, these types of queries always removed duplicate rows by means of Sort/Unique processing (i.e., sort then remove adjacent duplicates). Now they can be implemented by hashing, which will not produce sorted output. If an application relied on the output being in sorted order, the recommended fix is to add an `ORDER BY` clause. As a short-term workaround, the previous behavior can be restored by disabling `enable_hashagg`, but that is a very performance-expensive fix. `SELECT DISTINCT ON` never uses hashing, however, so its behavior is unchanged.
- Force child tables to inherit `CHECK` constraints from parents (Alex Hunsaker, Nikhil Sontakke, Tom)

  Formerly it was possible to drop such a constraint from a child table, allowing rows that violate the constraint to be visible when scanning the parent table. This was deemed inconsistent, as well as contrary to SQL standard.
- Disallow negative `LIMIT` or `OFFSET` values, rather than treating them as zero (Simon)
- Disallow `LOCK TABLE` outside a transaction block (Tom)

  Such an operation is useless because the lock would be released immediately.
- Sequences now contain an additional `start_value` column (Zoltan Boszormenyi)

  This supports `ALTER SEQUENCE ... RESTART`.

E.79.2.4. Functions and Operators

- Make `numeric` zero raised to a fractional power return `0`, rather than throwing an error, and make `numeric` zero raised to the zero power return `1`, rather than error (Bruce)

  This matches the longstanding `float8` behavior.

- Allow unary minus of floating-point values to produce minus zero (Tom)

  The changed behavior is more IEEE-standard compliant.

- Throw an error if an escape character is the last character in a `LIKE` pattern (i.e., it has nothing to escape) (Tom)

  Previously, such an escape character was silently ignored, thus possibly masking application logic errors.

- Remove `~=~` and `~<>~` operators formerly used for `LIKE` index comparisons (Tom)

  Pattern indexes now use the regular equality operator.

- `xpath()` now passes its arguments to libxml without any changes (Andrew)

  This means that the XML argument must be a well-formed XML document. The previous coding attempted to allow XML fragments, but it did not work well.

- Make `xmlelement()` format attribute values just like content values (Peter)

  Previously, attribute values were formatted according to the normal SQL output behavior, which is sometimes at odds with XML rules.

- Rewrite memory management for libxml-using functions (Tom)

  This change should avoid some compatibility problems with use of libxml in PL/Perl and other add-on code.

- Adopt a faster algorithm for hash functions (Kenneth Marshall, based on work of Bob Jenkins)

  Many of the built-in hash functions now deliver different results on little-endian and big-endian platforms.

E.79.2.4.1. Temporal Functions and Operators

- `DateStyle` no longer controls `interval` output formatting; instead there is a new variable `IntervalStyle` (Ron Mayer)
- Improve consistency of handling of fractional seconds in `timestamp` and `interval` output (Ron Mayer)

  This may result in displaying a different number of fractional digits than before, or rounding instead of truncating.

- Make `to_char()`'s localized month/day names depend on `LC_TIME`, not `LC_MESSAGES` (Euler Taveira de Oliveira)
- Cause `to_date()` and `to_timestamp()` to more consistently report errors for invalid input (Brendan Jurd)

  Previous versions would often ignore or silently misread input that did not match the format string. Such cases will now result in an error.

- Fix `to_timestamp()` to not require upper/lower case matching for meridian (`AM`/`PM`) and era (`BC`/`AD`) format designations (Brendan Jurd)

For example, input value ad now matches the format string AD.

E.79.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 8.4 and the previous major release.

E.79.3.1. Performance

- Improve optimizer statistics calculations (Jan Urbanski, Tom)

  In particular, estimates for full-text-search operators are greatly improved.

- Allow SELECT DISTINCT and UNION/INTERSECT/EXCEPT to use hashing (Tom)

  This means that these types of queries no longer automatically produce sorted output.

- Create explicit concepts of semi-joins and anti-joins (Tom)

  This work formalizes our previous ad-hoc treatment of IN (SELECT ...) clauses, and extends it to EXISTS and NOT EXISTS clauses. It should result in significantly better planning of EXISTS and NOT EXISTS queries. In general, logically equivalent IN and EXISTS clauses should now have similar performance, whereas previously IN often won.

- Improve optimization of sub-selects beneath outer joins (Tom)

  Formerly, a sub-select or view could not be optimized very well if it appeared within the nullable side of an outer join and contained non-strict expressions (for instance, constants) in its result list.

- Improve the performance of text_position() and related functions by using Boyer-Moore-Horspool searching (David Rowley)

  This is particularly helpful for long search patterns.

- Reduce I/O load of writing the statistics collection file by writing the file only when requested (Martin Pihlak)

- Improve performance for bulk inserts (Robert Haas, Simon)

- Increase the default value of default_statistics_target from 10 to 100 (Greg Sabino Mullane, Tom)

  The maximum value was also increased from 1000 to 10000.

- Perform constraint_exclusion checking by default in queries involving inheritance or UNION ALL (Tom)

  A new constraint_exclusion setting, partition, was added to specify this behavior.

- Allow I/O read-ahead for bitmap index scans (Greg Stark)

  The amount of read-ahead is controlled by effective_io_concurrency. This feature is available only if the kernel has posix_fadvise() support.

- Inline simple set-returning SQL functions in FROM clauses (Richard Rowell)

- Improve performance of multi-batch hash joins by providing a special case for join key values that are especially common in the outer relation (Bryce Cutt, Ramon Lawrence)

- Reduce volume of temporary data in multi-batch hash joins by suppressing "physical tlist" optimization (Michael Henderson, Ramon Lawrence)
- Avoid waiting for idle-in-transaction sessions during `CREATE INDEX CONCURRENTLY` (Simon)
- Improve performance of shared cache invalidation (Tom)

E.79.3.2. Server

E.79.3.2.1. Settings

- Convert many `postgresql.conf` settings to enumerated values so that `pg_settings` can display the valid values (Magnus)
- Add `cursor_tuple_fraction` parameter to control the fraction of a cursor's rows that the planner assumes will be fetched (Robert Hell)
- Allow underscores in the names of custom variable classes in `postgresql.conf` (Tom)

E.79.3.2.2. Authentication and security

- Remove support for the (insecure) `crypt` authentication method (Magnus)

  This effectively obsoletes pre-PostgreSQL 7.2 client libraries, as there is no longer any non-plaintext password method that they can use.
- Support regular expressions in `pg_ident.conf` (Magnus)
- Allow Kerberos/GSSAPI parameters to be changed without restarting the postmaster (Magnus)
- Support SSL certificate chains in server certificate file (Andrew Gierth)

  Including the full certificate chain makes the client able to verify the certificate without having all intermediate CA certificates present in the local store, which is often the case for commercial CAs.
- Report appropriate error message for combination of `MD5` authentication and `db_user_namespace` enabled (Bruce)

E.79.3.2.3. `pg_hba.conf`

- Change all authentication options to use `name=value` syntax (Magnus)

  This makes incompatible changes to the `ldap`, `pam` and `ident` authentication methods. All `pg_hba.conf` entries with these methods need to be rewritten using the new format.
- Remove the `ident sameuser` option, instead making that behavior the default if no usermap is specified (Magnus)
- Allow a usermap parameter for all external authentication methods (Magnus)

  Previously a usermap was only supported for `ident` authentication.
- Add `clientcert` option to control requesting of a client certificate (Magnus)

  Previously this was controlled by the presence of a root certificate file in the server's data directory.
- Add `cert` authentication method to allow *user* authentication via SSL certificates (Magnus)

Previously SSL certificates could only verify that the client had access to a certificate, not authenticate a user.

- Allow `krb5`, `gssapi` and `sspi` realm and `krb5` host settings to be specified in `pg_hba.conf` (Magnus)

  These override the settings in `postgresql.conf`.

- Add `include_realm` parameter for `krb5`, `gssapi`, and `sspi` methods (Magnus)

  This allows identical usernames from different realms to be authenticated as different database users using usermaps.

- Parse `pg_hba.conf` fully when it is loaded, so that errors are reported immediately (Magnus)

  Previously, most errors in the file wouldn't be detected until clients tried to connect, so an erroneous file could render the system unusable. With the new behavior, if an error is detected during reload then the bad file is rejected and the postmaster continues to use its old copy.

- Show all parsing errors in `pg_hba.conf` instead of aborting after the first one (Selena Deckelmann)

- Support `ident` authentication over Unix-domain sockets on Solaris (Garick Hamlin)

E.79.3.2.4. Continuous Archiving

- Provide an option to `pg_start_backup()` to force its implied checkpoint to finish as quickly as possible (Tom)

  The default behavior avoids excess I/O consumption, but that is pointless if no concurrent query activity is going on.

- Make `pg_stop_backup()` wait for modified WAL files to be archived (Simon)

  This guarantees that the backup is valid at the time `pg_stop_backup()` completes.

- When archiving is enabled, rotate the last WAL segment at shutdown so that all transactions can be archived immediately (Guillaume Smet, Heikki)

- Delay "smart" shutdown while a continuous archiving base backup is in progress (Laurenz Albe)

- Cancel a continuous archiving base backup if "fast" shutdown is requested (Laurenz Albe)

- Allow `recovery.conf` boolean variables to take the same range of string values as `postgresql.conf` boolean variables (Bruce)

E.79.3.2.5. Monitoring

- Add `pg_conf_load_time()` to report when the PostgreSQL configuration files were last loaded (George Gensure)

- Add `pg_terminate_backend()` to safely terminate a backend (the `SIGTERM` signal works also) (Tom, Bruce)

  While it's always been possible to `SIGTERM` a single backend, this was previously considered unsupported; and testing of the case found some bugs that are now fixed.

- Add ability to track user-defined functions' call counts and runtimes (Martin Pihlak)

  Function statistics appear in a new system view, `pg_stat_user_functions`. Tracking is controlled by the new parameter `track_functions`.

- Allow specification of the maximum query string size in `pg_stat_activity` via new `track_activity_query_size` parameter (Thomas Lee)
- Increase the maximum line length sent to syslog, in hopes of improving performance (Tom)
- Add read-only configuration variables `segment_size`, `wal_block_size`, and `wal_segment_size` (Bernd Helmle)
- When reporting a deadlock, report the text of all queries involved in the deadlock to the server log (Itagaki Takahiro)
- Add `pg_stat_get_activity(pid)` function to return information about a specific process id (Magnus)
- Allow the location of the server's statistics file to be specified via `stats_temp_directory` (Magnus)

  This allows the statistics file to be placed in a RAM-resident directory to reduce I/O requirements. On startup/shutdown, the file is copied to its traditional location (`$PGDATA/global/`) so it is preserved across restarts.

E.79.3.3. Queries

- Add support for `WINDOW` functions (Hitoshi Harada)
- Add support for `WITH` clauses (CTEs), including `WITH RECURSIVE` (Yoshiyuki Asaba, Tatsuo Ishii, Tom)
- Add `TABLE` command (Peter)

  `TABLE tablename` is a SQL standard short-hand for `SELECT * FROM tablename`.
- Allow `AS` to be optional when specifying a `SELECT` (or `RETURNING`) column output label (Hiroshi Saito)

  This works so long as the column label is not any PostgreSQL keyword; otherwise `AS` is still needed.
- Support set-returning functions in `SELECT` result lists even for functions that return their result via a tuplestore (Tom)

  In particular, this means that functions written in PL/pgSQL and other PL languages can now be called this way.
- Support set-returning functions in the output of aggregation and grouping queries (Tom)
- Allow `SELECT FOR UPDATE`/`SHARE` to work on inheritance trees (Tom)
- Add infrastructure for SQL/MED (Martin Pihlak, Peter)

  There are no remote or external SQL/MED capabilities yet, but this change provides a standardized and future-proof system for managing connection information for modules like `dblink` and `plproxy`.
- Invalidate cached plans when referenced schemas, functions, operators, or operator classes are modified (Martin Pihlak, Tom)

  This improves the system's ability to respond to on-the-fly DDL changes.
- Allow comparison of composite types and allow arrays of anonymous composite types (Tom)

This allows constructs such as `row(1, 1.1) = any (array[row(7, 7.7), row(1, 1.0)])`. This is particularly useful in recursive queries.

- Add support for Unicode string literal and identifier specifications using code points, e.g. `U&'d\0061t\+000061'` (Peter)
- Reject `\000` in string literals and `COPY` data (Tom)

  Previously, this was accepted but had the effect of terminating the string contents.
- Improve the parser's ability to report error locations (Tom)

  An error location is now reported for many semantic errors, such as mismatched datatypes, that previously could not be localized.

E.79.3.3.1. TRUNCATE

- Support statement-level `ON TRUNCATE` triggers (Simon)
- Add `RESTART`/`CONTINUE IDENTITY` options for `TRUNCATE TABLE` (Zoltan Boszormenyi)

  The start value of a sequence can be changed by `ALTER SEQUENCE START WITH`.
- Allow `TRUNCATE tab1, tab1` to succeed (Bruce)
- Add a separate `TRUNCATE` permission (Robert Haas)

E.79.3.3.2. EXPLAIN

- Make `EXPLAIN VERBOSE` show the output columns of each plan node (Tom)

  Previously `EXPLAIN VERBOSE` output an internal representation of the query plan. (That behavior is now available via `debug_print_plan`.)
- Make `EXPLAIN` identify subplans and initplans with individual labels (Tom)
- Make `EXPLAIN` honor `debug_print_plan` (Tom)
- Allow `EXPLAIN` on `CREATE TABLE AS` (Peter)

E.79.3.3.3. LIMIT/OFFSET

- Allow sub-selects in `LIMIT` and `OFFSET` (Tom)
- Add SQL-standard syntax for `LIMIT`/`OFFSET` capabilities (Peter)

  To wit, `OFFSET num {ROW|ROWS} FETCH {FIRST|NEXT} [num] {ROW|ROWS} ONLY`.

E.79.3.4. Object Manipulation

- Add support for column-level privileges (Stephen Frost, KaiGai Kohei)
- Refactor multi-object `DROP` operations to reduce the need for `CASCADE` (Alex Hunsaker)

  For example, if table `B` has a dependency on table `A`, the command `DROP TABLE A, B` no longer requires the `CASCADE` option.

- Fix various problems with concurrent `DROP` commands by ensuring that locks are taken before we begin to drop dependencies of an object (Tom)
- Improve reporting of dependencies during `DROP` commands (Tom)
- Add `WITH [NO] DATA` clause to `CREATE TABLE AS`, per the SQL standard (Peter, Tom)
- Add support for user-defined I/O conversion casts (Heikki)
- Allow `CREATE AGGREGATE` to use an `internal` transition datatype (Tom)
- Add `LIKE` clause to `CREATE TYPE` (Tom)

  This simplifies creation of data types that use the same internal representation as an existing type.
- Allow specification of the type category and "preferred" status for user-defined base types (Tom)

  This allows more control over the coercion behavior of user-defined types.
- Allow `CREATE OR REPLACE VIEW` to add columns to the end of a view (Robert Haas)

E.79.3.4.1. `ALTER`

- Add `ALTER TYPE RENAME` (Petr Jelinek)
- Add `ALTER SEQUENCE ... RESTART` (with no parameter) to reset a sequence to its initial value (Zoltan Boszormenyi)
- Modify the `ALTER TABLE` syntax to allow all reasonable combinations for tables, indexes, sequences, and views (Tom)

  This change allows the following new syntaxes:

  - `ALTER SEQUENCE OWNER TO`
  - `ALTER VIEW ALTER COLUMN SET/DROP DEFAULT`
  - `ALTER VIEW OWNER TO`
  - `ALTER VIEW SET SCHEMA`

  There is no actual new functionality here, but formerly you had to say `ALTER TABLE` to do these things, which was confusing.
- Add support for the syntax `ALTER TABLE ... ALTER COLUMN ... SET DATA TYPE` (Peter)

  This is SQL-standard syntax for functionality that was already supported.
- Make `ALTER TABLE SET WITHOUT OIDS` rewrite the table to physically remove `OID` values (Tom)

  Also, add `ALTER TABLE SET WITH OIDS` to rewrite the table to add `OID`s.

E.79.3.4.2. Database Manipulation

- Improve reporting of `CREATE`/`DROP`/`RENAME DATABASE` failure when uncommitted prepared transactions are the cause (Tom)
- Make `LC_COLLATE` and `LC_CTYPE` into per-database settings (Radek Strnad, Heikki)

  This makes collation similar to encoding, which was always configurable per database.
- Improve checks that the database encoding, collation (`LC_COLLATE`), and character classes (`LC_CTYPE`) match (Heikki, Tom)

Note in particular that a new database's encoding and locale settings can be changed only when copying from `template0`. This prevents possibly copying data that doesn't match the settings.

- Add `ALTER DATABASE SET TABLESPACE` to move a database to a new tablespace (Guillaume Lelarge, Bernd Helmle)

E.79.3.5. Utility Operations

- Add a `VERBOSE` option to the `CLUSTER` command and clusterdb (Jim Cox)
- Decrease memory requirements for recording pending trigger events (Tom)

E.79.3.5.1. Indexes

- Dramatically improve the speed of building and accessing hash indexes (Tom Raney, Shreya Bhargava)

  This allows hash indexes to be sometimes faster than btree indexes. However, hash indexes are still not crash-safe.
- Make hash indexes store only the hash code, not the full value of the indexed column (Xiao Meng)

  This greatly reduces the size of hash indexes for long indexed values, improving performance.
- Implement fast update option for GIN indexes (Teodor, Oleg)

  This option greatly improves update speed at a small penalty in search speed.
- `xxx_pattern_ops` indexes can now be used for simple equality comparisons, not only for `LIKE` (Tom)

E.79.3.5.2. Full Text Indexes

- Remove the requirement to use `@@@` when doing GIN weighted lookups on full text indexes (Tom, Teodor)

  The normal `@@` text search operator can be used instead.
- Add an optimizer selectivity function for `@@` text search operations (Jan Urbanski)
- Allow prefix matching in full text searches (Teodor Sigaev, Oleg Bartunov)
- Support multi-column GIN indexes (Teodor Sigaev)
- Improve support for Nepali language and Devanagari alphabet (Teodor)

E.79.3.5.3. `VACUUM`

- Track free space in separate per-relation "fork" files (Heikki)

  Free space discovered by `VACUUM` is now recorded in `*_fsm` files, rather than in a fixed-sized shared memory area. The `max_fsm_pages` and `max_fsm_relations` settings have been removed, greatly simplifying administration of free space management.
- Add a visibility map to track pages that do not require vacuuming (Heikki)

This allows VACUUM to avoid scanning all of a table when only a portion of the table needs vacuuming. The visibility map is stored in per-relation "fork" files.

- Add vacuum_freeze_table_age parameter to control when VACUUM should ignore the visibility map and do a full table scan to freeze tuples (Heikki)
- Track transaction snapshots more carefully (Alvaro)

  This improves VACUUM's ability to reclaim space in the presence of long-running transactions.
- Add ability to specify per-relation autovacuum and TOAST parameters in CREATE TABLE (Alvaro, Euler Taveira de Oliveira)

  Autovacuum options used to be stored in a system table.
- Add --freeze option to vacuumdb (Bruce)

E.79.3.6. Data Types

- Add a CaseSensitive option for text search synonym dictionaries (Simon)
- Improve the precision of NUMERIC division (Tom)
- Add basic arithmetic operators for int2 with int8 (Tom)

  This eliminates the need for explicit casting in some situations.
- Allow UUID input to accept an optional hyphen after every fourth digit (Robert Haas)
- Allow on/off as input for the boolean data type (Itagaki Takahiro)
- Allow spaces around NaN in the input string for type numeric (Sam Mason)

E.79.3.6.1. Temporal Data Types

- Reject year 0 BC and years 000 and 0000 (Tom)

  Previously these were interpreted as 1 BC. (Note: years 0 and 00 are still assumed to be the year 2000.)
- Include SGT (Singapore time) in the default list of known time zone abbreviations (Tom)
- Support infinity and -infinity as values of type date (Tom)
- Make parsing of interval literals more standard-compliant (Tom, Ron Mayer)

  For example, INTERVAL '1' YEAR now does what it's supposed to.
- Allow interval fractional-seconds precision to be specified after the second keyword, for SQL standard compliance (Tom)

  Formerly the precision had to be specified after the keyword interval. (For backwards compatibility, this syntax is still supported, though deprecated.) Data type definitions will now be output using the standard format.
- Support the IS0 8601 interval syntax (Ron Mayer, Kevin Grittner)

  For example, INTERVAL 'P1Y2M3DT4H5M6.7S' is now supported.
- Add IntervalStyle parameter which controls how interval values are output (Ron Mayer)

Valid values are: `postgres`, `postgres_verbose`, `sql_standard`, `iso_8601`. This setting also controls the handling of negative `interval` input when only some fields have positive/negative designations.

- Improve consistency of handling of fractional seconds in `timestamp` and `interval` output (Ron Mayer)

E.79.3.6.2. Arrays

- Improve the handling of casts applied to `ARRAY[]` constructs, such as `ARRAY[...]::integer[]` (Brendan Jurd)

  Formerly PostgreSQL attempted to determine a data type for the `ARRAY[]` construct without reference to the ensuing cast. This could fail unnecessarily in many cases, in particular when the `ARRAY[]` construct was empty or contained only ambiguous entries such as `NULL`. Now the cast is consulted to determine the type that the array elements must be.
- Make SQL-syntax `ARRAY` dimensions optional to match the SQL standard (Peter)
- Add `array_ndims()` to return the number of dimensions of an array (Robert Haas)
- Add `array_length()` to return the length of an array for a specified dimension (Jim Nasby, Robert Haas, Peter Eisentraut)
- Add aggregate function `array_agg()`, which returns all aggregated values as a single array (Robert Haas, Jeff Davis, Peter)
- Add `unnest()`, which converts an array to individual row values (Tom)

  This is the opposite of `array_agg()`.
- Add `array_fill()` to create arrays initialized with a value (Pavel Stehule)
- Add `generate_subscripts()` to simplify generating the range of an array's subscripts (Pavel Stehule)

E.79.3.6.3. Wide-Value Storage (TOAST)

- Consider TOAST compression on values as short as 32 bytes (previously 256 bytes) (Greg Stark)
- Require 25% minimum space savings before using TOAST compression (previously 20% for small values and any-savings-at-all for large values) (Greg)
- Improve TOAST heuristics for rows that have a mix of large and small toastable fields, so that we prefer to push large values out of line and don't compress small values unnecessarily (Greg, Tom)

E.79.3.7. Functions

- Document that `setseed()` allows values from `-1` to `1` (not just `0` to `1`), and enforce the valid range (Kris Jurka)
- Add server-side function `lo_import(filename, oid)` (Tatsuo)
- Add `quote_nullable()`, which behaves like `quote_literal()` but returns the string `NULL` for a null argument (Brendan Jurd)

- Improve full text search `headline()` function to allow extracting several fragments of text (Sushant Sinha)
- Add `suppress_redundant_updates_trigger()` trigger function to avoid overhead for non-data-changing updates (Andrew)
- Add `div(numeric, numeric)` to perform `numeric` division without rounding (Tom)
- Add `timestamp` and `timestamptz` versions of `generate_series()` (Hitoshi Harada)

E.79.3.7.1. Object Information Functions

- Implement `current_query()` for use by functions that need to know the currently running query (Tomas Doran)
- Add `pg_get_keywords()` to return a list of the parser keywords (Dave Page)
- Add `pg_get_functiondef()` to see a function's definition (Abhijit Menon-Sen)
- Allow the second argument of `pg_get_expr()` to be zero when deparsing an expression that does not contain variables (Tom)
- Modify `pg_relation_size()` to use `regclass` (Heikki)

  `pg_relation_size(data_type_name)` no longer works.
- Add `boot_val` and `reset_val` columns to `pg_settings` output (Greg Smith)
- Add source file name and line number columns to `pg_settings` output for variables set in a configuration file (Magnus, Alvaro)

  For security reasons, these columns are only visible to superusers.
- Add support for `CURRENT_CATALOG`, `CURRENT_SCHEMA`, `SET CATALOG`, `SET SCHEMA` (Peter)

  These provide SQL-standard syntax for existing features.
- Add `pg_typeof()` which returns the data type of any value (Brendan Jurd)
- Make `version()` return information about whether the server is a 32- or 64-bit binary (Bruce)
- Fix the behavior of information schema columns `is_insertable_into` and `is_updatable` to be consistent (Peter)
- Improve the behavior of information schema `datetime_precision` columns (Peter)

  These columns now show zero for `date` columns, and 6 (the default precision) for `time`, `timestamp`, and `interval` without a declared precision, rather than showing null as formerly.
- Convert remaining builtin set-returning functions to use `OUT` parameters (Jaime Casanova)

  This makes it possible to call these functions without specifying a column list: `pg_show_all_settings()`, `pg_lock_status()`, `pg_prepared_xact()`, `pg_prepared_statement()`, `pg_cursor()`
- Make `pg_*_is_visible()` and `has_*_privilege()` functions return `NULL` for invalid OIDs, rather than reporting an error (Tom)
- Extend `has_*_privilege()` functions to allow inquiring about the OR of multiple privileges in one call (Stephen Frost, Tom)
- Add `has_column_privilege()` and `has_any_column_privilege()` functions (Stephen Frost, Tom)

E.79.3.7.2. Function Creation

- Support variadic functions (functions with a variable number of arguments) (Pavel Stehule)

  Only trailing arguments can be optional, and they all must be of the same data type.
- Support default values for function arguments (Pavel Stehule)
- Add `CREATE FUNCTION ... RETURNS TABLE` clause (Pavel Stehule)
- Allow SQL-language functions to return the output of an `INSERT`/`UPDATE`/`DELETE RETURNING` clause (Tom)

E.79.3.7.3. PL/pgSQL Server-Side Language

- Support `EXECUTE USING` for easier insertion of data values into a dynamic query string (Pavel Stehule)
- Allow looping over the results of a cursor using a `FOR` loop (Pavel Stehule)
- Support `RETURN QUERY EXECUTE` (Pavel Stehule)
- Improve the `RAISE` command (Pavel Stehule)
  - Support `DETAIL` and `HINT` fields
  - Support specification of the `SQLSTATE` error code
  - Support an exception name parameter
  - Allow `RAISE` without parameters in an exception block to re-throw the current error
- Allow specification of `SQLSTATE` codes in `EXCEPTION` lists (Pavel Stehule)

  This is useful for handling custom `SQLSTATE` codes.
- Support the `CASE` statement (Pavel Stehule)
- Make `RETURN QUERY` set the special `FOUND` and `GET DIAGNOSTICS ROW_COUNT` variables (Pavel Stehule)
- Make `FETCH` and `MOVE` set the `GET DIAGNOSTICS ROW_COUNT` variable (Andrew Gierth)
- Make `EXIT` without a label always exit the innermost loop (Tom)

  Formerly, if there were a `BEGIN` block more closely nested than any loop, it would exit that block instead. The new behavior matches Oracle(TM) and is also what was previously stated by our own documentation.
- Make processing of string literals and nested block comments match the main SQL parser's processing (Tom)

  In particular, the format string in `RAISE` now works the same as any other string literal, including being subject to `standard_conforming_strings`. This change also fixes other cases in which valid commands would fail when `standard_conforming_strings` is on.
- Avoid memory leakage when the same function is called at varying exception-block nesting depths (Tom)

E.79.3.8. Client Applications

- Fix `pg_ctl restart` to preserve command-line arguments (Bruce)
- Add `-w`/`--no-password` option that prevents password prompting in all utilities that have a `-W`/`--password` option (Peter)
- Remove `-q` (quiet) option of createdb, createuser, dropdb, dropuser (Peter)

  These options have had no effect since PostgreSQL 8.3.

E.79.3.8.1. psql

- Remove verbose startup banner; now just suggest `help` (Joshua Drake)
- Make `help` show common backslash commands (Greg Sabino Mullane)
- Add `\pset format wrapped` mode to wrap output to the screen width, or file/pipe output too if `\pset columns` is set (Bryce Nesbitt)
- Allow all supported spellings of boolean values in `\pset`, rather than just `on` and `off` (Bruce)

  Formerly, any string other than "off" was silently taken to mean `true`. psql will now complain about unrecognized spellings (but still take them as `true`).
- Use the pager for wide output (Bruce)
- Require a space between a one-letter backslash command and its first argument (Bernd Helmle)

  This removes a historical source of ambiguity.
- Improve tab completion support for schema-qualified and quoted identifiers (Greg Sabino Mullane)
- Add optional `on`/`off` argument for `\timing` (David Fetter)
- Display access control rights on multiple lines (Brendan Jurd, Andreas Scherbaum)
- Make `\l` show database access privileges (Andrew Gilligan)
- Make `\l+` show database sizes, if permissions allow (Andrew Gilligan)
- Add the `\ef` command to edit function definitions (Abhijit Menon-Sen)

E.79.3.8.2. psql \d commands*

- Make `\d*` commands that do not have a pattern argument show system objects only if the `S` modifier is specified (Greg Sabino Mullane, Bruce)

  The former behavior was inconsistent across different variants of `\d`, and in most cases it provided no easy way to see just user objects.
- Improve `\d*` commands to work with older PostgreSQL server versions (back to 7.4), not only the current server version (Guillaume Lelarge)
- Make `\d` show foreign-key constraints that reference the selected table (Kenneth D'Souza)
- Make `\d` on a sequence show its column values (Euler Taveira de Oliveira)
- Add column storage type and other relation options to the `\d+` display (Gregory Stark, Euler Taveira de Oliveira)
- Show relation size in `\dt+` output (Dickson S. Guedes)
- Show the possible values of `enum` types in `\dT+` (David Fetter)

- Allow `\dC` to accept a wildcard pattern, which matches either datatype involved in the cast (Tom)
- Add a function type column to `\df`'s output, and add options to list only selected types of functions (David Fetter)
- Make `\df` not hide functions that take or return type `cstring` (Tom)

  Previously, such functions were hidden because most of them are datatype I/O functions, which were deemed uninteresting. The new policy about hiding system functions by default makes this wart unnecessary.

E.79.3.8.3. pg_dump

- Add a `--no-tablespaces` option to pg_dump/pg_dumpall/pg_restore so that dumps can be restored to clusters that have non-matching tablespace layouts (Gavin Roy)
- Remove `-d` and `-D` options from pg_dump and pg_dumpall (Tom)

  These options were too frequently confused with the option to select a database name in other PostgreSQL client applications. The functionality is still available, but you must now spell out the long option name `--inserts` or `--column-inserts`.
- Remove `-i`/`--ignore-version` option from pg_dump and pg_dumpall (Tom)

  Use of this option does not throw an error, but it has no effect. This option was removed because the version checks are necessary for safety.
- Disable `statement_timeout` during dump and restore (Joshua Drake)
- Add pg_dump/pg_dumpall option `--lock-wait-timeout` (David Gould)

  This allows dumps to fail if unable to acquire a shared lock within the specified amount of time.
- Reorder pg_dump `--data-only` output to dump tables referenced by foreign keys before the referencing tables (Tom)

  This allows data loads when foreign keys are already present. If circular references make a safe ordering impossible, a `NOTICE` is issued.
- Allow pg_dump, pg_dumpall, and pg_restore to use a specified role (Benedek László)
- Allow pg_restore to use multiple concurrent connections to do the restore (Andrew)

  The number of concurrent connections is controlled by the option `--jobs`. This is supported only for custom-format archives.

E.79.3.9. Programming Tools

E.79.3.9.1. libpq

- Allow the `OID` to be specified when importing a large object, via new function `lo_import_with_oid()` (Tatsuo)
- Add "events" support (Andrew Chernow, Merlin Moncure)

  This adds the ability to register callbacks to manage private data associated with `PGconn` and `PGresult` objects.

- Improve error handling to allow the return of multiple error messages as multi-line error reports (Magnus)
- Make `PQexecParams()` and related functions return `PGRES_EMPTY_QUERY` for an empty query (Tom)

  They previously returned `PGRES_COMMAND_OK`.
- Document how to avoid the overhead of `WSACleanup()` on Windows (Andrew Chernow)
- Do not rely on Kerberos tickets to determine the default database username (Magnus)

  Previously, a Kerberos-capable build of libpq would use the principal name from any available Kerberos ticket as default database username, even if the connection wasn't using Kerberos authentication. This was deemed inconsistent and confusing. The default username is now determined the same way with or without Kerberos. Note however that the database username must still match the ticket when Kerberos authentication is used.

E.79.3.9.2. libpq SSL (Secure Sockets Layer) support

- Fix certificate validation for SSL connections (Magnus)

  libpq now supports verifying both the certificate and the name of the server when making SSL connections. If a root certificate is not available to use for verification, SSL connections will fail. The `sslmode` parameter is used to enable certificate verification and set the level of checking. The default is still not to do any verification, allowing connections to SSL-enabled servers without requiring a root certificate on the client.
- Support wildcard server certificates (Magnus)

  If a certificate CN starts with `*`, it will be treated as a wildcard when matching the hostname, allowing the use of the same certificate for multiple servers.
- Allow the file locations for client certificates to be specified (Mark Woodward, Alvaro, Magnus)
- Add a `PQinitOpenSSL` function to allow greater control over OpenSSL/libcrypto initialization (Andrew Chernow)
- Make libpq unregister its OpenSSL callbacks when no database connections remain open (Bruce, Magnus, Russell Smith)

  This is required for applications that unload the libpq library, otherwise invalid OpenSSL callbacks will remain.

E.79.3.9.3. ecpg

- Add localization support for messages (Euler Taveira de Oliveira)
- ecpg parser is now automatically generated from the server parser (Michael)

  Previously the ecpg parser was hand-maintained.

E.79.3.9.4. Server Programming Interface (SPI)

- Add support for single-use plans with out-of-line parameters (Tom)
- Add new `SPI_OK_REWRITTEN` return code for `SPI_execute()` (Heikki)

This is used when a command is rewritten to another type of command.

- Remove unnecessary inclusions from `executor/spi.h` (Tom)

  SPI-using modules might need to add some `#include` lines if they were depending on `spi.h` to include things for them.

E.79.3.10. Build Options

- Update build system to use Autoconf 2.61 (Peter)
- Require GNU bison for source code builds (Peter)

  This has effectively been required for several years, but now there is no infrastructure claiming to support other parser tools.
- Add pg_config `--htmldir` option (Peter)
- Pass `float4` by value inside the server (Zoltan Boszormenyi)

  Add configure option `--disable-float4-byval` to use the old behavior. External C functions that use old-style (version 0) call convention and pass or return `float4` values will be broken by this change, so you may need the configure option if you have such functions and don't want to update them.
- Pass `float8`, `int8`, and related datatypes by value inside the server on 64-bit platforms (Zoltan Boszormenyi)

  Add configure option `--disable-float8-byval` to use the old behavior. As above, this change might break old-style external C functions.
- Add configure options `--with-segsize`, `--with-blocksize`, `--with-wal-blocksize`, `--with-wal-segsize` (Zdenek Kotala, Tom)

  This simplifies build-time control over several constants that previously could only be changed by editing `pg_config_manual.h`.
- Allow threaded builds on Solaris 2.5 (Bruce)
- Use the system's `getopt_long()` on Solaris (Zdenek Kotala, Tom)

  This makes option processing more consistent with what Solaris users expect.
- Add support for the Sun Studio compiler on Linux (Julius Stroffek)
- Append the major version number to the backend gettext domain, and the `soname` major version number to libraries' gettext domain (Peter)

  This simplifies parallel installations of multiple versions.
- Add support for code coverage testing with gcov (Michelle Caisse)
- Allow out-of-tree builds on Mingw and Cygwin (Richard Evans)
- Fix the use of Mingw as a cross-compiling source platform (Peter)

E.79.3.11. Source Code

- Support 64-bit time zone data files (Heikki)

  This adds support for daylight saving time (DST) calculations beyond the year 2038.

- Deprecate use of platform's `time_t` data type (Tom)

  Some platforms have migrated to 64-bit `time_t`, some have not, and Windows can't make up its mind what it's doing. Define `pg_time_t` to have the same meaning as `time_t`, but always be 64 bits (unless the platform has no 64-bit integer type), and use that type in all module APIs and on-disk data formats.
- Fix bug in handling of the time zone database when cross-compiling (Richard Evans)
- Link backend object files in one step, rather than in stages (Peter)
- Improve gettext support to allow better translation of plurals (Peter)
- Add message translation support to the PL languages (Alvaro, Peter)
- Add more DTrace probes (Robert Lor)
- Enable DTrace support on Mac OS X Leopard and other non-Solaris platforms (Robert Lor)
- Simplify and standardize conversions between C strings and `text` datums, by providing common functions for the purpose (Brendan Jurd, Tom)
- Clean up the `include/catalog/` header files so that frontend programs can include them without including `postgres.h` (Zdenek Kotala)
- Make `name` char-aligned, and suppress zero-padding of `name` entries in indexes (Tom)
- Recover better if dynamically-loaded code executes `exit()` (Tom)
- Add a hook to let plug-ins monitor the executor (Itagaki Takahiro)
- Add a hook to allow the planner's statistics lookup behavior to be overridden (Simon Riggs)
- Add `shmem_startup_hook()` for custom shared memory requirements (Tom)
- Replace the index access method `amgetmulti` entry point with `amgetbitmap`, and extend the API for `amgettuple` to support run-time determination of operator lossiness (Heikki, Tom, Teodor)

  The API for GIN and GiST opclass `consistent` functions has been extended as well.
- Add support for partial-match searches in GIN indexes (Teodor Sigaev, Oleg Bartunov)
- Replace `pg_class` column `reltriggers` with boolean `relhastriggers` (Simon)

  Also remove unused `pg_class` columns `relukeys`, `relfkeys`, and `relrefs`.
- Add a `relistemp` column to `pg_class` to ease identification of temporary tables (Tom)
- Move platform FAQs into the main documentation (Peter)
- Prevent parser input files from being built with any conflicts (Peter)
- Add support for the `KOI8U` (Ukrainian) encoding (Peter)
- Add Japanese message translations (Japan PostgreSQL Users Group)

  This used to be maintained as a separate project.
- Fix problem when setting `LC_MESSAGES` on MSVC-built systems (Hiroshi Inoue, Hiroshi Saito, Magnus)

E.79.3.12. Contrib

- Add `contrib/auto_explain` to automatically run `EXPLAIN` on queries exceeding a specified duration (Itagaki Takahiro, Tom)
- Add `contrib/btree_gin` to allow GIN indexes to handle more datatypes (Oleg, Teodor)

- Add `contrib/citext` to provide a case-insensitive, multibyte-aware text data type (David Wheeler)
- Add `contrib/pg_stat_statements` for server-wide tracking of statement execution statistics (Itagaki Takahiro)
- Add duration and query mode options to `contrib/pgbench` (Itagaki Takahiro)
- Make `contrib/pgbench` use table names `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`, rather than just `accounts`, `branches`, `history`, and `tellers` (Tom)

  This is to reduce the risk of accidentally destroying real data by running pgbench.
- Fix `contrib/pgstattuple` to handle tables and indexes with over 2 billion pages (Tatsuhito Kasahara)
- In `contrib/fuzzystrmatch`, add a version of the Levenshtein string-distance function that allows the user to specify the costs of insertion, deletion, and substitution (Volkan Yazici)
- Make `contrib/ltree` support multibyte encodings (laser)
- Enable `contrib/dblink` to use connection information stored in the SQL/MED catalogs (Joe Conway)
- Improve `contrib/dblink`'s reporting of errors from the remote server (Joe Conway)
- Make `contrib/dblink` set `client_encoding` to match the local database's encoding (Joe Conway)

  This prevents encoding problems when communicating with a remote database that uses a different encoding.
- Make sure `contrib/dblink` uses a password supplied by the user, and not accidentally taken from the server's `.pgpass` file (Joe Conway)

  This is a minor security enhancement.
- Add `fsm_page_contents()` to `contrib/pageinspect` (Heikki)
- Modify `get_raw_page()` to support free space map (`*_fsm`) files. Also update `contrib/pg_freespacemap`.
- Add support for multibyte encodings to `contrib/pg_trgm` (Teodor)
- Rewrite `contrib/intagg` to use new functions `array_agg()` and `unnest()` (Tom)
- Make `contrib/pg_standby` recover all available WAL before failover (Fujii Masao, Simon, Heikki)

  To make this work safely, you now need to set the new `recovery_end_command` option in `recovery.conf` to clean up the trigger file after failover. pg_standby will no longer remove the trigger file itself.
- `contrib/pg_standby`'s `-l` option is now a no-op, because it is unsafe to use a symlink (Simon)

E.80. Release 8.3.23

Release Date: 2013-02-07

This release contains a variety of fixes from 8.3.22. For information about new features in the 8.3 major release, see Section E.103.

This is expected to be the last PostgreSQL release in the 8.3.X series. Users are encouraged to update to a newer release branch soon.

E.80.1. Migration to Version 8.3.23

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.80.2. Changes

- Prevent execution of `enum_recv` from SQL (Tom Lane)

  The function was misdeclared, allowing a simple SQL command to crash the server. In principle an attacker might be able to use it to examine the contents of server memory. Our thanks to Sumit Soni (via Secunia SVCRP) for reporting this issue. (CVE-2013-0255)

- Fix SQL grammar to allow subscripting or field selection from a sub-SELECT result (Tom Lane)

- Protect against race conditions when scanning `pg_tablespace` (Stephen Frost, Tom Lane)

  `CREATE DATABASE` and `DROP DATABASE` could misbehave if there were concurrent updates of `pg_tablespace` entries.

- Prevent `DROP OWNED` from trying to drop whole databases or tablespaces (Álvaro Herrera)

  For safety, ownership of these objects must be reassigned, not dropped.

- Prevent misbehavior when a `RowExpr` or `XmlExpr` is parse-analyzed twice (Andres Freund, Tom Lane)

  This mistake could be user-visible in contexts such as `CREATE TABLE LIKE INCLUDING INDEXES`.

- Improve defenses against integer overflow in hashtable sizing calculations (Jeff Davis)

- Ensure that non-ASCII prompt strings are translated to the correct code page on Windows (Alexander Law, Noah Misch)

  This bug affected psql and some other client programs.

- Fix possible crash in psql's `\?` command when not connected to a database (Meng Qingzhong)

- Fix one-byte buffer overrun in libpq's `PQprintTuples` (Xi Wang)

  This ancient function is not used anywhere by PostgreSQL itself, but it might still be used by some client code.

- Rearrange configure's tests for supplied functions so it is not fooled by bogus exports from libedit/libreadline (Christoph Berg)

- Ensure Windows build number increases over time (Magnus Hagander)

- Make pgxs build executables with the right `.exe` suffix when cross-compiling for Windows (Zoltan Boszormenyi)

- Add new timezone abbreviation `FET` (Tom Lane)

  This is now used in some eastern-European time zones.

E.81. Release 8.3.22

Release Date: 2012-12-06

This release contains a variety of fixes from 8.3.21. For information about new features in the 8.3 major release, see Section E.103.

The PostgreSQL community will stop releasing updates for the 8.3.X release series in February 2013. Users are encouraged to update to a newer release branch soon.

E.81.1. Migration to Version 8.3.22

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.81.2. Changes

- Fix multiple bugs associated with `CREATE INDEX CONCURRENTLY` (Andres Freund, Tom Lane)

  Fix `CREATE INDEX CONCURRENTLY` to use in-place updates when changing the state of an index's `pg_index` row. This prevents race conditions that could cause concurrent sessions to miss updating the target index, thus resulting in corrupt concurrently-created indexes.

  Also, fix various other operations to ensure that they ignore invalid indexes resulting from a failed `CREATE INDEX CONCURRENTLY` command. The most important of these is `VACUUM`, because an auto-vacuum could easily be launched on the table before corrective action can be taken to fix or remove the invalid index.

- Avoid corruption of internal hash tables when out of memory (Hitoshi Harada)

- Fix planning of non-strict equivalence clauses above outer joins (Tom Lane)

  The planner could derive incorrect constraints from a clause equating a non-strict construct to something else, for example `WHERE COALESCE(foo, 0) = 0` when `foo` is coming from the nullable side of an outer join.

- Improve planner's ability to prove exclusion constraints from equivalence classes (Tom Lane)

- Fix partial-row matching in hashed subplans to handle cross-type cases correctly (Tom Lane)

  This affects multicolumn `NOT IN` subplans, such as `WHERE (a, b) NOT IN (SELECT x, y FROM ...)` when for instance `b` and `y` are `int4` and `int8` respectively. This mistake led to wrong answers or crashes depending on the specific datatypes involved.

- Acquire buffer lock when re-fetching the old tuple for an `AFTER ROW UPDATE/DELETE` trigger (Andres Freund)

  In very unusual circumstances, this oversight could result in passing incorrect data to the precheck logic for a foreign-key enforcement trigger. That could result in a crash, or in an incorrect decision about whether to fire the trigger.

- Fix `REASSIGN OWNED` to handle grants on tablespaces (Álvaro Herrera)

- Ignore incorrect `pg_attribute` entries for system columns for views (Tom Lane)

Views do not have any system columns. However, we forgot to remove such entries when converting a table to a view. That's fixed properly for 9.3 and later, but in previous branches we need to defend against existing mis-converted views.

- Fix rule printing to dump `INSERT INTO table DEFAULT VALUES` correctly (Tom Lane)
- Guard against stack overflow when there are too many `UNION`/`INTERSECT`/`EXCEPT` clauses in a query (Tom Lane)
- Prevent platform-dependent failures when dividing the minimum possible integer value by -1 (Xi Wang, Tom Lane)
- Fix possible access past end of string in date parsing (Hitoshi Harada)
- Produce an understandable error message if the length of the path name for a Unix-domain socket exceeds the platform-specific limit (Tom Lane, Andrew Dunstan)

  Formerly, this would result in something quite unhelpful, such as "Non-recoverable failure in name resolution".
- Fix memory leaks when sending composite column values to the client (Tom Lane)
- Make pg_ctl more robust about reading the `postmaster.pid` file (Heikki Linnakangas)

  Fix race conditions and possible file descriptor leakage.
- Fix possible crash in psql if incorrectly-encoded data is presented and the `client_encoding` setting is a client-only encoding, such as SJIS (Jiang Guiqing)
- Fix bugs in the `restore.sql` script emitted by pg_dump in `tar` output format (Tom Lane)

  The script would fail outright on tables whose names include upper-case characters. Also, make the script capable of restoring data in `--inserts` mode as well as the regular COPY mode.
- Fix pg_restore to accept POSIX-conformant `tar` files (Brian Weaver, Tom Lane)

  The original coding of pg_dump's `tar` output mode produced files that are not fully conformant with the POSIX standard. This has been corrected for version 9.3. This patch updates previous branches so that they will accept both the incorrect and the corrected formats, in hopes of avoiding compatibility problems when 9.3 comes out.
- Fix pg_resetxlog to locate `postmaster.pid` correctly when given a relative path to the data directory (Tom Lane)

  This mistake could lead to pg_resetxlog not noticing that there is an active postmaster using the data directory.
- Fix libpq's `lo_import()` and `lo_export()` functions to report file I/O errors properly (Tom Lane)
- Fix ecpg's processing of nested structure pointer variables (Muhammad Usama)
- Make `contrib/pageinspect`'s btree page inspection functions take buffer locks while examining pages (Tom Lane)
- Fix pgxs support for building loadable modules on AIX (Tom Lane)

  Building modules outside the original source tree didn't work on AIX.
- Update time zone data files to tzdata release 2012j for DST law changes in Cuba, Israel, Jordan, Libya, Palestine, Western Samoa, and portions of Brazil.

E.82. Release 8.3.21

Release Date: 2012-09-24

This release contains a variety of fixes from 8.3.20. For information about new features in the 8.3 major release, see Section E.103.

The PostgreSQL community will stop releasing updates for the 8.3.X release series in February 2013. Users are encouraged to update to a newer release branch soon.

E.82.1. Migration to Version 8.3.21

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.82.2. Changes

- Improve page-splitting decisions in GiST indexes (Alexander Korotkov, Robert Haas, Tom Lane)

  Multi-column GiST indexes might suffer unexpected bloat due to this error.

- Fix cascading privilege revoke to stop if privileges are still held (Tom Lane)

  If we revoke a grant option from some role *X*, but *X* still holds that option via a grant from someone else, we should not recursively revoke the corresponding privilege from role(s) *Y* that *X* had granted it to.

- Fix handling of `SIGFPE` when PL/Perl is in use (Andres Freund)

  Perl resets the process's `SIGFPE` handler to `SIG_IGN`, which could result in crashes later on. Restore the normal Postgres signal handler after initializing PL/Perl.

- Prevent PL/Perl from crashing if a recursive PL/Perl function is redefined while being executed (Tom Lane)

- Work around possible misoptimization in PL/Perl (Tom Lane)

  Some Linux distributions contain an incorrect version of `pthread.h` that results in incorrect compiled code in PL/Perl, leading to crashes if a PL/Perl function calls another one that throws an error.

- Update time zone data files to tzdata release 2012f for DST law changes in Fiji

E.83. Release 8.3.20

Release Date: 2012-08-17

This release contains a variety of fixes from 8.3.19. For information about new features in the 8.3 major release, see Section E.103.

The PostgreSQL community will stop releasing updates for the 8.3.X release series in February 2013. Users are encouraged to update to a newer release branch soon.

E.83.1. Migration to Version 8.3.20

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.83.2. Changes

- Prevent access to external files/URLs via XML entity references (Noah Misch, Tom Lane)

  `xml_parse()` would attempt to fetch external files or URLs as needed to resolve DTD and entity references in an XML value, thus allowing unprivileged database users to attempt to fetch data with the privileges of the database server. While the external data wouldn't get returned directly to the user, portions of it could be exposed in error messages if the data didn't parse as valid XML; and in any case the mere ability to check existence of a file might be useful to an attacker. (CVE-2012-3489)

- Prevent access to external files/URLs via `contrib/xml2`'s `xslt_process()` (Peter Eisentraut)

  libxslt offers the ability to read and write both files and URLs through stylesheet commands, thus allowing unprivileged database users to both read and write data with the privileges of the database server. Disable that through proper use of libxslt's security options. (CVE-2012-3488)

  Also, remove `xslt_process()`'s ability to fetch documents and stylesheets from external files/URLs. While this was a documented "feature", it was long regarded as a bad idea. The fix for CVE-2012-3489 broke that capability, and rather than expend effort on trying to fix it, we're just going to summarily remove it.

- Prevent too-early recycling of btree index pages (Noah Misch)

  When we allowed read-only transactions to skip assigning XIDs, we introduced the possibility that a deleted btree page could be recycled while a read-only transaction was still in flight to it. This would result in incorrect index search results. The probability of such an error occurring in the field seems very low because of the timing requirements, but nonetheless it should be fixed.

- Fix crash-safety bug with newly-created-or-reset sequences (Tom Lane)

  If `ALTER SEQUENCE` was executed on a freshly created or reset sequence, and then precisely one `nextval()` call was made on it, and then the server crashed, WAL replay would restore the sequence to a state in which it appeared that no `nextval()` had been done, thus allowing the first sequence value to be returned again by the next `nextval()` call. In particular this could manifest for `serial` columns, since creation of a serial column's sequence includes an `ALTER SEQUENCE OWNED BY` step.

- Ensure the `backup_label` file is fsync'd after `pg_start_backup()` (Dave Kerr)

- Back-patch 9.1 improvement to compress the fsync request queue (Robert Haas)

  This improves performance during checkpoints. The 9.1 change has now seen enough field testing to seem safe to back-patch.

- Only allow autovacuum to be auto-canceled by a directly blocked process (Tom Lane)

  The original coding could allow inconsistent behavior in some cases; in particular, an autovacuum could get canceled after less than `deadlock_timeout` grace period.

- Improve logging of autovacuum cancels (Robert Haas)
- Fix log collector so that `log_truncate_on_rotation` works during the very first log rotation after server start (Tom Lane)
- Ensure that a whole-row reference to a subquery doesn't include any extra `GROUP BY` or `ORDER BY` columns (Tom Lane)
- Disallow copying whole-row references in `CHECK` constraints and index definitions during `CREATE TABLE` (Tom Lane)

  This situation can arise in `CREATE TABLE` with `LIKE` or `INHERITS`. The copied whole-row variable was incorrectly labeled with the row type of the original table not the new one. Rejecting the case seems reasonable for `LIKE`, since the row types might well diverge later. For `INHERITS` we should ideally allow it, with an implicit coercion to the parent table's row type; but that will require more work than seems safe to back-patch.
- Fix memory leak in `ARRAY(SELECT ...)` subqueries (Heikki Linnakangas, Tom Lane)
- Fix extraction of common prefixes from regular expressions (Tom Lane)

  The code could get confused by quantified parenthesized subexpressions, such as `^(foo)?bar`. This would lead to incorrect index optimization of searches for such patterns.
- Report errors properly in `contrib/xml2`'s `xslt_process()` (Tom Lane)
- Update time zone data files to tzdata release 2012e for DST law changes in Morocco and Tokelau

E.84. Release 8.3.19

Release Date: 2012-06-04

This release contains a variety of fixes from 8.3.18. For information about new features in the 8.3 major release, see Section E.103.

E.84.1. Migration to Version 8.3.19

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.84.2. Changes

- Fix incorrect password transformation in `contrib/pgcrypto`'s DES `crypt()` function (Solar Designer)

  If a password string contained the byte value `0x80`, the remainder of the password was ignored, causing the password to be much weaker than it appeared. With this fix, the rest of the string is properly included in the DES hash. Any stored password values that are affected by this bug will thus no longer match, so the stored values may need to be updated. (CVE-2012-2143)

- Ignore `SECURITY DEFINER` and `SET` attributes for a procedural language's call handler (Tom Lane)

  Applying such attributes to a call handler could crash the server. (CVE-2012-2655)

- Allow numeric timezone offsets in `timestamp` input to be up to 16 hours away from UTC (Tom Lane)

  Some historical time zones have offsets larger than 15 hours, the previous limit. This could result in dumped data values being rejected during reload.

- Fix timestamp conversion to cope when the given time is exactly the last DST transition time for the current timezone (Tom Lane)

  This oversight has been there a long time, but was not noticed previously because most DST-using zones are presumed to have an indefinite sequence of future DST transitions.

- Fix `text` to `name` and `char` to `name` casts to perform string truncation correctly in multibyte encodings (Karl Schnaitter)

- Fix memory copying bug in `to_tsquery()` (Heikki Linnakangas)

- Fix slow session startup when `pg_attribute` is very large (Tom Lane)

  If `pg_attribute` exceeds one-fourth of `shared_buffers`, cache rebuilding code that is sometimes needed during session start would trigger the synchronized-scan logic, causing it to take many times longer than normal. The problem was particularly acute if many new sessions were starting at once.

- Ensure sequential scans check for query cancel reasonably often (Merlin Moncure)

  A scan encountering many consecutive pages that contain no live tuples would not respond to interrupts meanwhile.

- Ensure the Windows implementation of `PGSemaphoreLock()` clears `ImmediateInterruptOK` before returning (Tom Lane)

  This oversight meant that a query-cancel interrupt received later in the same query could be accepted at an unsafe time, with unpredictable but not good consequences.

- Show whole-row variables safely when printing views or rules (Abbas Butt, Tom Lane)

  Corner cases involving ambiguous names (that is, the name could be either a table or column name of the query) were printed in an ambiguous way, risking that the view or rule would be interpreted differently after dump and reload. Avoid the ambiguous case by attaching a no-op cast.

- Ensure autovacuum worker processes perform stack depth checking properly (Heikki Linnakangas)

  Previously, infinite recursion in a function invoked by auto-`ANALYZE` could crash worker processes.

- Fix logging collector to not lose log coherency under high load (Andrew Dunstan)

  The collector previously could fail to reassemble large messages if it got too busy.

- Fix logging collector to ensure it will restart file rotation after receiving SIGHUP (Tom Lane)

- Fix PL/pgSQL's `GET DIAGNOSTICS` command when the target is the function's first variable (Tom Lane)

- Fix several performance problems in pg_dump when the database contains many objects (Jeff Janes, Tom Lane)

  pg_dump could get very slow if the database contained many schemas, or if many objects are in dependency loops, or if there are many owned sequences.

- Fix contrib/dblink's dblink_exec() to not leak temporary database connections upon error (Tom Lane)
- Update time zone data files to tzdata release 2012c for DST law changes in Antarctica, Armenia, Chile, Cuba, Falkland Islands, Gaza, Haiti, Hebron, Morocco, Syria, and Tokelau Islands; also historical corrections for Canada.

E.85. Release 8.3.18

Release Date: 2012-02-27

This release contains a variety of fixes from 8.3.17. For information about new features in the 8.3 major release, see Section E.103.

E.85.1. Migration to Version 8.3.18

A dump/restore is not required for those running 8.3.X.

However, if you are upgrading from a version earlier than 8.3.17, see Section E.86.

E.85.2. Changes

- Require execute permission on the trigger function for CREATE TRIGGER (Robert Haas)

  This missing check could allow another user to execute a trigger function with forged input data, by installing it on a table he owns. This is only of significance for trigger functions marked SECURITY DEFINER, since otherwise trigger functions run as the table owner anyway. (CVE-2012-0866)
- Convert newlines to spaces in names written in pg_dump comments (Robert Haas)

  pg_dump was incautious about sanitizing object names that are emitted within SQL comments in its output script. A name containing a newline would at least render the script syntactically incorrect. Maliciously crafted object names could present a SQL injection risk when the script is reloaded. (CVE-2012-0868)
- Fix btree index corruption from insertions concurrent with vacuuming (Tom Lane)

  An index page split caused by an insertion could sometimes cause a concurrently-running VACUUM to miss removing index entries that it should remove. After the corresponding table rows are removed, the dangling index entries would cause errors (such as "could not read block N in file ...") or worse, silently wrong query results after unrelated rows are re-inserted at the now-free table locations. This bug has been present since release 8.2, but occurs so infrequently that it was not diagnosed until now. If you have reason to suspect that it has happened in your database, reindexing the affected index will fix things.
- Allow non-existent values for some settings in ALTER USER/DATABASE SET (Heikki Linnakangas)

  Allow default_text_search_config, default_tablespace, and temp_tablespaces to be set to names that are not known. This is because they might be known in another database where

the setting is intended to be used, or for the tablespace cases because the tablespace might not be created yet. The same issue was previously recognized for `search_path`, and these settings now act like that one.

- Track the OID counter correctly during WAL replay, even when it wraps around (Tom Lane)

  Previously the OID counter would remain stuck at a high value until the system exited replay mode. The practical consequences of that are usually nil, but there are scenarios wherein a standby server that's been promoted to master might take a long time to advance the OID counter to a reasonable value once values are needed.

- Fix regular expression back-references with `*` attached (Tom Lane)

  Rather than enforcing an exact string match, the code would effectively accept any string that satisfies the pattern sub-expression referenced by the back-reference symbol.

  A similar problem still afflicts back-references that are embedded in a larger quantified expression, rather than being the immediate subject of the quantifier. This will be addressed in a future PostgreSQL release.

- Fix recently-introduced memory leak in processing of `inet`/`cidr` values (Heikki Linnakangas)

  A patch in the December 2011 releases of PostgreSQL caused memory leakage in these operations, which could be significant in scenarios such as building a btree index on such a column.

- Avoid double close of file handle in syslogger on Windows (MauMau)

  Ordinarily this error was invisible, but it would cause an exception when running on a debug version of Windows.

- Fix I/O-conversion-related memory leaks in plpgsql (Andres Freund, Jan Urbanski, Tom Lane)

  Certain operations would leak memory until the end of the current function.

- Improve pg_dump's handling of inherited table columns (Tom Lane)

  pg_dump mishandled situations where a child column has a different default expression than its parent column. If the default is textually identical to the parent's default, but not actually the same (for instance, because of schema search path differences) it would not be recognized as different, so that after dump and restore the child would be allowed to inherit the parent's default. Child columns that are `NOT NULL` where their parent is not could also be restored subtly incorrectly.

- Fix pg_restore's direct-to-database mode for INSERT-style table data (Tom Lane)

  Direct-to-database restores from archive files made with `--inserts` or `--column-inserts` options fail when using pg_restore from a release dated September or December 2011, as a result of an oversight in a fix for another problem. The archive file itself is not at fault, and text-mode output is okay.

- Fix error in `contrib/intarray`'s `int[] & int[]` operator (Guillaume Lelarge)

  If the smallest integer the two input arrays have in common is 1, and there are smaller values in either array, then 1 would be incorrectly omitted from the result.

- Fix error detection in `contrib/pgcrypto`'s `encrypt_iv()` and `decrypt_iv()` (Marko Kreen)

  These functions failed to report certain types of invalid-input errors, and would instead return random garbage values for incorrect input.

- Fix one-byte buffer overrun in `contrib/test_parser` (Paul Guyot)

  The code would try to read one more byte than it should, which would crash in corner cases. Since `contrib/test_parser` is only example code, this is not a security issue in itself, but bad example code is still bad.

- Use `__sync_lock_test_and_set()` for spinlocks on ARM, if available (Martin Pitt)

  This function replaces our previous use of the `SWPB` instruction, which is deprecated and not available on ARMv6 and later. Reports suggest that the old code doesn't fail in an obvious way on recent ARM boards, but simply doesn't interlock concurrent accesses, leading to bizarre failures in multiprocess operation.

- Use `-fexcess-precision=standard` option when building with gcc versions that accept it (Andrew Dunstan)

  This prevents assorted scenarios wherein recent versions of gcc will produce creative results.

- Allow use of threaded Python on FreeBSD (Chris Rees)

  Our configure script previously believed that this combination wouldn't work; but FreeBSD fixed the problem, so remove that error check.

E.86. Release 8.3.17

Release Date: 2011-12-05

This release contains a variety of fixes from 8.3.16. For information about new features in the 8.3 major release, see Section E.103.

E.86.1. Migration to Version 8.3.17

A dump/restore is not required for those running 8.3.X.

However, a longstanding error was discovered in the definition of the `information_schema.referential_constraints` view. If you rely on correct results from that view, you should replace its definition as explained in the first changelog item below.

Also, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.86.2. Changes

- Fix bugs in `information_schema.referential_constraints` view (Tom Lane)

  This view was being insufficiently careful about matching the foreign-key constraint to the depended-on primary or unique key constraint. That could result in failure to show a foreign key constraint at all, or showing it multiple times, or claiming that it depends on a different constraint than the one it really does.

  Since the view definition is installed by initdb, merely upgrading will not fix the problem. If you need to fix this in an existing installation, you can (as a superuser) drop the `information_schema` schema then re-create it by sourcing *`SHAREDIR`*`/information_schema.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) This must be repeated in each database to be fixed.

- Fix TOAST-related data corruption during `CREATE TABLE dest AS SELECT * FROM src` or `INSERT INTO dest SELECT * FROM src` (Tom Lane)

If a table has been modified by `ALTER TABLE ADD COLUMN`, attempts to copy its data verbatim to another table could produce corrupt results in certain corner cases. The problem can only manifest in this precise form in 8.4 and later, but we patched earlier versions as well in case there are other code paths that could trigger the same bug.

- Fix race condition during toast table access from stale syscache entries (Tom Lane)

  The typical symptom was transient errors like "missing chunk number 0 for toast value NNNNN in pg_toast_2619", where the cited toast table would always belong to a system catalog.

- Make `DatumGetInetP()` unpack inet datums that have a 1-byte header, and add a new macro, `DatumGetInetPP()`, that does not (Heikki Linnakangas)

  This change affects no core code, but might prevent crashes in add-on code that expects `DatumGetInetP()` to produce an unpacked datum as per usual convention.

- Improve locale support in `money` type's input and output (Tom Lane)

  Aside from not supporting all standard `lc_monetary` formatting options, the input and output functions were inconsistent, meaning there were locales in which dumped `money` values could not be re-read.

- Don't let `transform_null_equals` affect `CASE foo WHEN NULL ...` constructs (Heikki Linnakangas)

  `transform_null_equals` is only supposed to affect `foo = NULL` expressions written directly by the user, not equality checks generated internally by this form of `CASE`.

- Change foreign-key trigger creation order to better support self-referential foreign keys (Tom Lane)

  For a cascading foreign key that references its own table, a row update will fire both the `ON UPDATE` trigger and the `CHECK` trigger as one event. The `ON UPDATE` trigger must execute first, else the `CHECK` will check a non-final state of the row and possibly throw an inappropriate error. However, the firing order of these triggers is determined by their names, which generally sort in creation order since the triggers have auto-generated names following the convention "RI_ConstraintTrigger_NNNN". A proper fix would require modifying that convention, which we will do in 9.2, but it seems risky to change it in existing releases. So this patch just changes the creation order of the triggers. Users encountering this type of error should drop and re-create the foreign key constraint to get its triggers into the right order.

- Avoid floating-point underflow while tracking buffer allocation rate (Greg Matthews)

  While harmless in itself, on certain platforms this would result in annoying kernel log messages.

- Preserve blank lines within commands in psql's command history (Robert Haas)

  The former behavior could cause problems if an empty line was removed from within a string literal, for example.

- Fix pg_dump to dump user-defined casts between auto-generated types, such as table rowtypes (Tom Lane)

- Use the preferred version of xsubpp to build PL/Perl, not necessarily the operating system's main copy (David Wheeler and Alex Hunsaker)

- Fix incorrect coding in `contrib/dict_int` and `contrib/dict_xsyn` (Tom Lane)

  Some functions incorrectly assumed that memory returned by `palloc()` is guaranteed zeroed.

- Honor query cancel interrupts promptly in `pgstatindex()` (Robert Haas)

- Ensure VPATH builds properly install all server header files (Peter Eisentraut)

- Shorten file names reported in verbose error messages (Peter Eisentraut)

Regular builds have always reported just the name of the C file containing the error message call, but VPATH builds formerly reported an absolute path name.

- Fix interpretation of Windows timezone names for Central America (Tom Lane)

  Map "Central America Standard Time" to `CST6`, not `CST6CDT`, because DST is generally not observed anywhere in Central America.

- Update time zone data files to tzdata release 2011n for DST law changes in Brazil, Cuba, Fiji, Palestine, Russia, and Samoa; also historical corrections for Alaska and British East Africa.

E.87. Release 8.3.16

Release Date: 2011-09-26

This release contains a variety of fixes from 8.3.15. For information about new features in the 8.3 major release, see Section E.103.

E.87.1. Migration to Version 8.3.16

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.87.2. Changes

- Fix bugs in indexing of in-doubt HOT-updated tuples (Tom Lane)

  These bugs could result in index corruption after reindexing a system catalog. They are not believed to affect user indexes.

- Fix multiple bugs in GiST index page split processing (Heikki Linnakangas)

  The probability of occurrence was low, but these could lead to index corruption.

- Fix possible buffer overrun in `tsvector_concat()` (Tom Lane)

  The function could underestimate the amount of memory needed for its result, leading to server crashes.

- Fix crash in `xml_recv` when processing a "standalone" parameter (Tom Lane)

- Avoid possibly accessing off the end of memory in `ANALYZE` and in SJIS-2004 encoding conversion (Noah Misch)

  This fixes some very-low-probability server crash scenarios.

- Fix race condition in relcache init file invalidation (Tom Lane)

  There was a window wherein a new backend process could read a stale init file but miss the inval messages that would tell it the data is stale. The result would be bizarre failures in catalog accesses, typically "could not read block 0 in file ..." later during startup.

- Fix memory leak at end of a GiST index scan (Tom Lane)

Commands that perform many separate GiST index scans, such as verification of a new GiST-based exclusion constraint on a table already containing many rows, could transiently require large amounts of memory due to this leak.

- Fix performance problem when constructing a large, lossy bitmap (Tom Lane)
- Fix array- and path-creating functions to ensure padding bytes are zeroes (Tom Lane)

  This avoids some situations where the planner will think that semantically-equal constants are not equal, resulting in poor optimization.
- Work around gcc 4.6.0 bug that breaks WAL replay (Tom Lane)

  This could lead to loss of committed transactions after a server crash.
- Fix dump bug for `VALUES` in a view (Tom Lane)
- Disallow `SELECT FOR UPDATE/SHARE` on sequences (Tom Lane)

  This operation doesn't work as expected and can lead to failures.
- Defend against integer overflow when computing size of a hash table (Tom Lane)
- Fix cases where `CLUSTER` might attempt to access already-removed TOAST data (Tom Lane)
- Fix portability bugs in use of credentials control messages for "peer" authentication (Tom Lane)
- Fix SSPI login when multiple roundtrips are required (Ahmed Shinwari, Magnus Hagander)

  The typical symptom of this problem was "The function requested is not supported" errors during SSPI login.
- Fix typo in `pg_srand48` seed initialization (Andres Freund)

  This led to failure to use all bits of the provided seed. This function is not used on most platforms (only those without `srandom`), and the potential security exposure from a less-random-than-expected seed seems minimal in any case.
- Avoid integer overflow when the sum of `LIMIT` and `OFFSET` values exceeds 2^63 (Heikki Linnakangas)
- Add overflow checks to `int4` and `int8` versions of `generate_series()` (Robert Haas)
- Fix trailing-zero removal in `to_char()` (Marti Raudsepp)

  In a format with `FM` and no digit positions after the decimal point, zeroes to the left of the decimal point could be removed incorrectly.
- Fix `pg_size_pretty()` to avoid overflow for inputs close to 2^63 (Tom Lane)
- In pg_ctl, support silent mode for service registrations on Windows (MauMau)
- Fix psql's counting of script file line numbers during `COPY` from a different file (Tom Lane)
- Fix pg_restore's direct-to-database mode for `standard_conforming_strings` (Tom Lane)

  pg_restore could emit incorrect commands when restoring directly to a database server from an archive file that had been made with `standard_conforming_strings` set to `on`.
- Fix write-past-buffer-end and memory leak in libpq's LDAP service lookup code (Albe Laurenz)
- In libpq, avoid failures when using nonblocking I/O and an SSL connection (Martin Pihlak, Tom Lane)
- Improve libpq's handling of failures during connection startup (Tom Lane)

  In particular, the response to a server report of `fork()` failure during SSL connection startup is now saner.

- Improve libpq's error reporting for SSL failures (Tom Lane)
- Make ecpglib write `double` values with 15 digits precision (Akira Kurosawa)
- In ecpglib, be sure `LC_NUMERIC` setting is restored after an error (Michael Meskes)
- Apply upstream fix for blowfish signed-character bug (CVE-2011-2483) (Tom Lane)

  `contrib/pg_crypto`'s blowfish encryption code could give wrong results on platforms where char is signed (which is most), leading to encrypted passwords being weaker than they should be.
- Fix memory leak in `contrib/seg` (Heikki Linnakangas)
- Fix `pgstatindex()` to give consistent results for empty indexes (Tom Lane)
- Allow building with perl 5.14 (Alex Hunsaker)
- Update configure script's method for probing existence of system functions (Tom Lane)

  The version of autoconf we used in 8.3 and 8.2 could be fooled by compilers that perform link-time optimization.
- Fix assorted issues with build and install file paths containing spaces (Tom Lane)
- Update time zone data files to tzdata release 2011i for DST law changes in Canada, Egypt, Russia, Samoa, and South Sudan.

E.88. Release 8.3.15

Release Date: 2011-04-18

This release contains a variety of fixes from 8.3.14. For information about new features in the 8.3 major release, see Section E.103.

E.88.1. Migration to Version 8.3.15

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.88.2. Changes

- Disallow including a composite type in itself (Tom Lane)

  This prevents scenarios wherein the server could recurse infinitely while processing the composite type. While there are some possible uses for such a structure, they don't seem compelling enough to justify the effort required to make sure it always works safely.
- Avoid potential deadlock during catalog cache initialization (Nikhil Sontakke)

  In some cases the cache loading code would acquire share lock on a system index before locking the index's catalog. This could deadlock against processes trying to acquire exclusive locks in the other, more standard order.

- Fix dangling-pointer problem in `BEFORE ROW UPDATE` trigger handling when there was a concurrent update to the target tuple (Tom Lane)

  This bug has been observed to result in intermittent "cannot extract system attribute from virtual tuple" failures while trying to do `UPDATE RETURNING ctid`. There is a very small probability of more serious errors, such as generating incorrect index entries for the updated tuple.

- Disallow `DROP TABLE` when there are pending deferred trigger events for the table (Tom Lane)

  Formerly the `DROP` would go through, leading to "could not open relation with OID nnn" errors when the triggers were eventually fired.

- Fix PL/Python memory leak involving array slices (Daniel Popowich)

- Fix pg_restore to cope with long lines (over 1KB) in TOC files (Tom Lane)

- Put in more safeguards against crashing due to division-by-zero with overly enthusiastic compiler optimization (Aurelien Jarno)

- Support use of dlopen() in FreeBSD and OpenBSD on MIPS (Tom Lane)

  There was a hard-wired assumption that this system function was not available on MIPS hardware on these systems. Use a compile-time test instead, since more recent versions have it.

- Fix compilation failures on HP-UX (Heikki Linnakangas)

- Fix version-incompatibility problem with libintl on Windows (Hiroshi Inoue)

- Fix usage of xcopy in Windows build scripts to work correctly under Windows 7 (Andrew Dunstan)

  This affects the build scripts only, not installation or usage.

- Fix path separator used by pg_regress on Cygwin (Andrew Dunstan)

- Update time zone data files to tzdata release 2011f for DST law changes in Chile, Cuba, Falkland Islands, Morocco, Samoa, and Turkey; also historical corrections for South Australia, Alaska, and Hawaii.

E.89. Release 8.3.14

Release Date: 2011-01-31

This release contains a variety of fixes from 8.3.13. For information about new features in the 8.3 major release, see Section E.103.

E.89.1. Migration to Version 8.3.14

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.89.2. Changes

- Avoid failures when `EXPLAIN` tries to display a simple-form `CASE` expression (Tom Lane)

If the CASE's test expression was a constant, the planner could simplify the CASE into a form that confused the expression-display code, resulting in "unexpected CASE WHEN clause" errors.

- Fix assignment to an array slice that is before the existing range of subscripts (Tom Lane)

  If there was a gap between the newly added subscripts and the first pre-existing subscript, the code miscalculated how many entries needed to be copied from the old array's null bitmap, potentially leading to data corruption or crash.

- Avoid unexpected conversion overflow in planner for very distant date values (Tom Lane)

  The date type supports a wider range of dates than can be represented by the timestamp types, but the planner assumed it could always convert a date to timestamp with impunity.

- Fix pg_restore's text output for large objects (BLOBs) when standard_conforming_strings is on (Tom Lane)

  Although restoring directly to a database worked correctly, string escaping was incorrect if pg_restore was asked for SQL text output and standard_conforming_strings had been enabled in the source database.

- Fix erroneous parsing of tsquery values containing ... & !(subexpression) | ... (Tom Lane)

  Queries containing this combination of operators were not executed correctly. The same error existed in contrib/intarray's query_int type and contrib/ltree's ltxtquery type.

- Fix buffer overrun in contrib/intarray's input function for the query_int type (Apple)

  This bug is a security risk since the function's return address could be overwritten. Thanks to Apple Inc's security team for reporting this issue and supplying the fix. (CVE-2010-4015)

- Fix bug in contrib/seg's GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a seg column. If you have such an index, consider REINDEXing it after installing this update. (This is identical to the bug that was fixed in contrib/cube in the previous update.)

E.90. Release 8.3.13

Release Date: 2010-12-16

This release contains a variety of fixes from 8.3.12. For information about new features in the 8.3 major release, see Section E.103.

E.90.1. Migration to Version 8.3.13

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.90.2. Changes

- Force the default `wal_sync_method` to be `fdatasync` on Linux (Tom Lane, Marti Raudsepp)

  The default on Linux has actually been `fdatasync` for many years, but recent kernel changes caused PostgreSQL to choose `open_datasync` instead. This choice did not result in any performance improvement, and caused outright failures on certain filesystems, notably `ext4` with the `data=journal` mount option.

- Fix assorted bugs in WAL replay logic for GIN indexes (Tom Lane)

  This could result in "bad buffer id: 0" failures or corruption of index contents during replication.

- Fix recovery from base backup when the starting checkpoint WAL record is not in the same WAL segment as its redo point (Jeff Davis)

- Fix persistent slowdown of autovacuum workers when multiple workers remain active for a long time (Tom Lane)

  The effective `vacuum_cost_limit` for an autovacuum worker could drop to nearly zero if it processed enough tables, causing it to run extremely slowly.

- Add support for detecting register-stack overrun on `IA64` (Tom Lane)

  The `IA64` architecture has two hardware stacks. Full prevention of stack-overrun failures requires checking both.

- Add a check for stack overflow in `copyObject()` (Tom Lane)

  Certain code paths could crash due to stack overflow given a sufficiently complex query.

- Fix detection of page splits in temporary GiST indexes (Heikki Linnakangas)

  It is possible to have a "concurrent" page split in a temporary index, if for example there is an open cursor scanning the index when an insertion is done. GiST failed to detect this case and hence could deliver wrong results when execution of the cursor continued.

- Avoid memory leakage while `ANALYZE`'ing complex index expressions (Tom Lane)

- Ensure an index that uses a whole-row Var still depends on its table (Tom Lane)

  An index declared like `create index i on t (foo(t.*))` would not automatically get dropped when its table was dropped.

- Do not "inline" a SQL function with multiple `OUT` parameters (Tom Lane)

  This avoids a possible crash due to loss of information about the expected result rowtype.

- Behave correctly if `ORDER BY`, `LIMIT`, `FOR UPDATE`, or `WITH` is attached to the `VALUES` part of `INSERT ... VALUES` (Tom Lane)

- Fix constant-folding of `COALESCE()` expressions (Tom Lane)

  The planner would sometimes attempt to evaluate sub-expressions that in fact could never be reached, possibly leading to unexpected errors.

- Fix postmaster crash when connection acceptance (`accept()` or one of the calls made immediately after it) fails, and the postmaster was compiled with GSSAPI support (Alexander Chernikov)

- Fix missed unlink of temporary files when `log_temp_files` is active (Tom Lane)

  If an error occurred while attempting to emit the log message, the unlink was not done, resulting in accumulation of temp files.

- Add print functionality for `InhRelation` nodes (Tom Lane)

This avoids a failure when `debug_print_parse` is enabled and certain types of query are executed.

- Fix incorrect calculation of distance from a point to a horizontal line segment (Tom Lane)

  This bug affected several different geometric distance-measurement operators.

- Fix PL/pgSQL's handling of "simple" expressions to not fail in recursion or error-recovery cases (Tom Lane)

- Fix PL/Python's handling of set-returning functions (Jan Urbanski)

  Attempts to call SPI functions within the iterator generating a set result would fail.

- Fix bug in `contrib/cube`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `cube` column. If you have such an index, consider `REINDEX`ing it after installing this update.

- Don't emit "identifier will be truncated" notices in `contrib/dblink` except when creating new connections (Itagaki Takahiro)

- Fix potential coredump on missing public key in `contrib/pgcrypto` (Marti Raudsepp)

- Fix memory leak in `contrib/xml2`'s XPath query functions (Tom Lane)

- Update time zone data files to tzdata release 2010o for DST law changes in Fiji and Samoa; also historical corrections for Hong Kong.

E.91. Release 8.3.12

Release Date: 2010-10-04

This release contains a variety of fixes from 8.3.11. For information about new features in the 8.3 major release, see Section E.103.

E.91.1. Migration to Version 8.3.12

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.91.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)
- Treat exit code 128 (`ERROR_WAIT_NO_CHILDREN`) as non-fatal on Windows (Magnus Hagander)

  Under high load, Windows processes will sometimes fail at startup with this error code. Formerly the postmaster treated this as a panic condition and restarted the whole database, but that seems to be an overreaction.
- Fix incorrect usage of non-strict OR joinclauses in Append indexscans (Tom Lane)

  This is a back-patch of an 8.4 fix that was missed in the 8.3 branch. This corrects an error introduced in 8.3.8 that could cause incorrect results for outer joins when the inner relation is an inheritance tree or `UNION ALL` subquery.
- Fix possible duplicate scans of `UNION ALL` member relations (Tom Lane)
- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.
- Fix failure to mark cached plans as transient (Tom Lane)

  If a plan is prepared while `CREATE INDEX CONCURRENTLY` is in progress for one of the referenced tables, it is supposed to be re-planned once the index is ready for use. This was not happening reliably.
- Reduce PANIC to ERROR in some occasionally-reported btree failure cases, and provide additional detail in the resulting error messages (Tom Lane)

  This should improve the system's robustness with corrupted indexes.
- Prevent show_session_authorization() from crashing within autovacuum processes (Tom Lane)
- Defend against functions returning setof record where not all the returned rows are actually of the same rowtype (Tom Lane)
- Fix possible failure when hashing a pass-by-reference function result (Tao Ma, Tom Lane)
- Improve merge join's handling of NULLs in the join columns (Tom Lane)

  A merge join can now stop entirely upon reaching the first NULL, if the sort order is such that NULLs sort high.
- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

  This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.

- Avoid recursion while assigning XIDs to heavily-nested subtransactions (Andres Freund, Robert Haas)

  The original coding could result in a crash if there was limited stack space.

- Avoid holding open old WAL segments in the walwriter process (Magnus Hagander, Heikki Linnakangas)

  The previous coding would prevent removal of no-longer-needed segments.

- Fix `log_line_prefix`'s `%i` escape, which could produce junk early in backend startup (Tom Lane)

- Fix possible data corruption in `ALTER TABLE ... SET TABLESPACE` when archiving is enabled (Jeff Davis)

- Allow `CREATE DATABASE` and `ALTER DATABASE ... SET TABLESPACE` to be interrupted by query-cancel (Guillaume Lelarge)

- Fix `REASSIGN OWNED` to handle operator classes and families (Asko Tiidumaa)

- Fix possible core dump when comparing two empty `tsquery` values (Tom Lane)

- Fix `LIKE`'s handling of patterns containing `%` followed by _ (Tom Lane)

  We've fixed this before, but there were still some incorrectly-handled cases.

- In PL/Python, defend against null pointer results from `PyCObject_AsVoidPtr` and `PyCObject_FromVoidPtr` (Peter Eisentraut)

- Make psql recognize `DISCARD ALL` as a command that should not be encased in a transaction block in autocommit-off mode (Itagaki Takahiro)

- Fix ecpg to process data from `RETURNING` clauses correctly (Michael Meskes)

- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)

- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)

- Fix `contrib/dblink` to handle connection names longer than 62 bytes correctly (Itagaki Takahiro)

- Add `hstore(text, text)` function to `contrib/hstore` (Robert Haas)

  This function is the recommended substitute for the now-deprecated => operator. It was backpatched so that future-proofed code can be used with older server versions. Note that the patch will be effective only after `contrib/hstore` is installed or reinstalled in a particular database. Users might prefer to execute the `CREATE FUNCTION` command by hand, instead.

- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)

- Update time zone data files to tzdata release 2010l for DST law changes in Egypt and Palestine; also historical corrections for Finland.

  This change also adds new names for two Micronesian timezones: Pacific/Chuuk is now preferred over Pacific/Truk (and the preferred abbreviation is CHUT not TRUT) and Pacific/Pohnpei is preferred over Pacific/Ponape.

- Make Windows' "N. Central Asia Standard Time" timezone map to Asia/Novosibirsk, not Asia/Almaty (Magnus Hagander)

  Microsoft changed the DST behavior of this zone in the timezone update from KB976098. Asia/Novosibirsk is a better match to its new behavior.

E.92. Release 8.3.11

Release Date: 2010-05-17

This release contains a variety of fixes from 8.3.10. For information about new features in the 8.3 major release, see Section E.103.

E.92.1. Migration to Version 8.3.11

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.92.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b` variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Fix possible crash if a cache reset message is received during rebuild of a relcache entry (Heikki)

  This error was introduced in 8.3.10 while fixing a related failure.

- Apply per-function GUC settings while running the language validator for the function (Itagaki Takahiro)

  This avoids failures if the function's code is invalid without the setting; an example is that SQL functions may not parse if the `search_path` is not correct.

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

  Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Ensure the archiver process responds to changes in `archive_command` as soon as possible (Tom)
- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)
- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)
- Prevent infinite recursion in psql when expanding a variable that refers to itself (Tom)
- Fix psql's `\copy` to not add spaces around a dot within `\copy (select ...)` (Tom)

  Addition of spaces around the decimal point in a numeric literal would result in a syntax error.
- Fix unnecessary "GIN indexes do not support whole-index scans" errors for unsatisfiable queries using `contrib/intarray` operators (Tom)
- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)
- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.
- Avoid possible crashes in syslogger process on Windows (Heikki)
- Deal more robustly with incomplete time zone information in the Windows registry (Magnus)
- Update the set of known Windows time zone names (Magnus)
- Update time zone data files to tzdata release 2010j for DST law changes in Argentina, Australian Antarctic, Bangladesh, Mexico, Morocco, Pakistan, Palestine, Russia, Syria, Tunisia; also historical corrections for Taiwan.

  Also, add `PKST` (Pakistan Summer Time) to the default set of timezone abbreviations.

E.93. Release 8.3.10

Release Date: 2010-03-15

This release contains a variety of fixes from 8.3.9. For information about new features in the 8.3 major release, see Section E.103.

E.93.1. Migration to Version 8.3.10

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.93.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.

- Fix possible deadlock during backend startup (Tom)
- Fix possible crashes due to not handling errors during relcache reload cleanly (Tom)
- Fix possible crash due to use of dangling pointer to a cached plan (Tatsuo)
- Fix possible crashes when trying to recover from a failure in subtransaction start (Tom)
- Fix server memory leak associated with use of savepoints and a client encoding different from server's encoding (Tom)
- Fix incorrect WAL data emitted during end-of-recovery cleanup of a GIST index page split (Yoichi Hirai)

  This would result in index corruption, or even more likely an error during WAL replay, if we were unlucky enough to crash during end-of-recovery cleanup after having completed an incomplete GIST insertion.

- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).

- Fix integer-to-bit-string conversions to handle the first fractional byte correctly when the output bit width is wider than the given integer by something other than a multiple of 8 bits (Tom)
- Fix some cases of pathologically slow regular expression matching (Tom)
- Fix assorted crashes in `xml` processing caused by sloppy memory management (Tom)

  This is a back-patch of changes first applied in 8.4. The 8.3 code was known buggy, but the new code was sufficiently different to not want to back-patch it until it had gotten some field testing.

- Fix bug with trying to update a field of an element of a composite-type array column (Tom)
- Fix the `STOP WAL LOCATION` entry in backup history files to report the next WAL segment's name when the end location is exactly at a segment boundary (Itagaki Takahiro)
- Fix some more cases of temporary-file leakage (Heikki)

  This corrects a problem introduced in the previous minor release. One case that failed is when a plpgsql function returning set is called within another function's exception handler.

- Improve constraint exclusion processing of boolean-variable cases, in particular make it possible to exclude a partition that has a "bool_column = false" constraint (Tom)
- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.

- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)
- Fix possible infinite loop if `SSL_read` or `SSL_write` fails without setting `errno` (Tom)

  This is reportedly possible with some Windows versions of openssl.
- Disallow GSSAPI authentication on local connections, since it requires a hostname to function correctly (Magnus)
- Make ecpg report the proper SQLSTATE if the connection disappears (Michael)
- Fix psql's `numericlocale` option to not format strings it shouldn't in latex and troff output formats (Heikki)
- Make psql return the correct exit status (3) when `ON_ERROR_STOP` and `--single-transaction` are both specified and an error occurs during the implied `COMMIT` (Bruce)
- Fix plpgsql failure in one case where a composite column is set to NULL (Tom)
- Fix possible failure when calling PL/Perl functions from PL/PerlU or vice versa (Tim Bunce)
- Add `volatile` markings in PL/Python to avoid possible compiler-specific misbehavior (Zdenek Kotala)
- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

  The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.
- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)
- Allow zero-dimensional arrays in `contrib/ltree` operations (Tom)

  This case was formerly rejected as an error, but it's more convenient to treat it the same as a zero-element array. In particular this avoids unnecessary failures when an `ltree` operation is applied to the result of `ARRAY(SELECT ...)` and the sub-select returns no rows.
- Fix assorted crashes in `contrib/xml2` caused by sloppy memory management (Tom)
- Make building of `contrib/xml2` more robust on Windows (Andrew)
- Fix race condition in Windows signal handling (Radu Ilie)

  One known symptom of this bug is that rows in `pg_listener` could be dropped under heavy load.
- Update time zone data files to tzdata release 2010e for DST law changes in Bangladesh, Chile, Fiji, Mexico, Paraguay, Samoa.

E.94. Release 8.3.9

Release Date: 2009-12-14

This release contains a variety of fixes from 8.3.8. For information about new features in the 8.3 major release, see Section E.103.

E.94.1. Migration to Version 8.3.9

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.8, see Section E.95.

E.94.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).

- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).

- Fix possible crash during backend-startup-time cache initialization (Tom)

- Avoid crash on empty thesaurus dictionary (Tom)

- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.

- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.

- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)

- Ensure that shared tuple-level locks held by prepared transactions are not ignored (Heikki)

- Fix premature drop of temporary files used for a cursor that is accessed within a subtransaction (Heikki)

- Fix memory leak in syslogger process when rotating to a new CSV logfile (Tom)

- Fix Windows permission-downgrade logic (Jesse Morris)

  This fixes some cases where the database failed to start on Windows, often with misleading error messages such as "could not locate matching postgres executable".

- Fix incorrect logic for GiST index page splits, when the split depends on a non-first column of the index (Paul Ramsey)

- Don't error out if recycling or removing an old WAL file fails at the end of checkpoint (Heikki)

  It's better to treat the problem as non-fatal and allow the checkpoint to complete. Future checkpoints will retry the removal. Such problems are not expected in normal operation, but have been seen to be caused by misdesigned Windows anti-virus and backup software.

- Ensure WAL files aren't repeatedly archived on Windows (Heikki)

  This is another symptom that could happen if some other process interfered with deletion of a no-longer-needed file.

- Fix PAM password processing to be more robust (Tom)

The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.

- Raise the maximum authentication token (Kerberos ticket) size in GSSAPI and SSPI authentication methods (Ian Turner)

  While the old 2000-byte limit was more than enough for Unix Kerberos implementations, tickets issued by Windows Domain Controllers can be much larger.

- Re-enable collection of access statistics for sequences (Akira Kurosawa)

  This used to work but was broken in 8.3.

- Fix processing of ownership dependencies during `CREATE OR REPLACE FUNCTION` (Tom)

- Fix incorrect handling of `WHERE x=x` conditions (Tom)

  In some cases these could get ignored as redundant, but they aren't — they're equivalent to `x IS NOT NULL`.

- Make text search parser accept underscores in XML attributes (Peter)

- Fix encoding handling in `xml` binary input (Heikki)

  If the XML header doesn't specify an encoding, we now assume UTF-8 by default; the previous handling was inconsistent.

- Fix bug with calling `plperl` from `plperlu` or vice versa (Tom)

  An error exit from the inner function could result in crashes due to failure to re-select the correct Perl interpreter for the outer function.

- Fix session-lifespan memory leak when a PL/Perl function is redefined (Tom)

- Ensure that Perl arrays are properly converted to PostgreSQL arrays when returned by a set-returning PL/Perl function (Andrew Dunstan, Abhijit Menon-Sen)

  This worked correctly already for non-set-returning functions.

- Fix rare crash in exception processing in PL/Python (Peter)

- In `contrib/pg_standby`, disable triggering failover with a signal on Windows (Fujii Masao)

  This never did anything useful, because Windows doesn't have Unix-style signals, but recent changes made it actually crash.

- Ensure psql's flex module is compiled with the correct system header definitions (Tom)

  This fixes build failures on platforms where `--enable-largefile` causes incompatible changes in the generated code.

- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)

- Update the timezone abbreviation files to match current reality (Joachim Wieland)

  This includes adding `IDT` and `SGT` to the default timezone abbreviation set.

- Update time zone data files to tzdata release 2009s for DST law changes in Antarctica, Argentina, Bangladesh, Fiji, Novokuznetsk, Pakistan, Palestine, Samoa, Syria; also historical corrections for Hong Kong.

E.95. Release 8.3.8

Release Date: 2009-09-09

This release contains a variety of fixes from 8.3.7. For information about new features in the 8.3 major release, see Section E.103.

E.95.1. Migration to Version 8.3.8

A dump/restore is not required for those running 8.3.X. However, if you have any hash indexes on `interval` columns, you must `REINDEX` them after updating to 8.3.8. Also, if you are upgrading from a version earlier than 8.3.5, see Section E.98.

E.95.2. Changes

- Fix Windows shared-memory allocation code (Tsutomu Yamada, Magnus)

  This bug led to the often-reported "could not reattach to shared memory" error message.

- Force WAL segment switch during `pg_start_backup()` (Heikki)

  This avoids corner cases that could render a base backup unusable.

- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

  This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)

- Make `LOAD` of an already-loaded loadable module into a no-op (Tom)

  Formerly, `LOAD` would attempt to unload and re-load the module, but this is unsafe and not all that useful.

- Disallow empty passwords during LDAP authentication (Magnus)

- Fix handling of sub-SELECTs appearing in the arguments of an outer-level aggregate function (Tom)

- Fix bugs associated with fetching a whole-row value from the output of a Sort or Materialize plan node (Tom)

- Prevent `synchronize_seqscans` from changing the results of scrollable and `WITH HOLD` cursors (Tom)

- Revert planner change that disabled partial-index and constraint exclusion optimizations when there were more than 100 clauses in an AND or OR list (Tom)

- Fix hash calculation for data type `interval` (Tom)

  This corrects wrong results for hash joins on interval values. It also changes the contents of hash indexes on interval columns. If you have any such indexes, you must `REINDEX` them after updating.

- Treat `to_char(..., 'TH')` as an uppercase ordinal suffix with `'HH'/'HH12'` (Heikki)

  It was previously handled as `'th'` (lowercase).

- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Fix calculation of distance between a point and a line segment (Tom)

  This led to incorrect results from a number of geometric operators.
- Fix `money` data type to work in locales where currency amounts have no fractional digits, e.g. Japan (Itagaki Takahiro)
- Fix `LIKE` for case where pattern contains `%_` (Tom)
- Properly round datetime input like `00:12:57.9999999999999999999999999999` (Tom)
- Fix memory leaks in XML operations (Tom)
- Fix poor choice of page split point in GiST R-tree operator classes (Teodor)
- Ensure that a "fast shutdown" request will forcibly terminate open sessions, even if a "smart shutdown" was already in progress (Fujii Masao)
- Avoid performance degradation in bulk inserts into GIN indexes when the input values are (nearly) in sorted order (Tom)
- Correctly enforce NOT NULL domain constraints in some contexts in PL/pgSQL (Tom)
- Fix portability issues in plperl initialization (Andrew Dunstan)
- Fix pg_ctl to not go into an infinite loop if `postgresql.conf` is empty (Jeff Davis)
- Improve pg_dump's efficiency when there are many large objects (Tamas Vincze)
- Use `SIGUSR1`, not `SIGQUIT`, as the failover signal for pg_standby (Heikki)
- Make pg_standby's `maxretries` option behave as documented (Fujii Masao)
- Make `contrib/hstore` throw an error when a key or value is too long to fit in its data structure, rather than silently truncating it (Andrew Gierth)
- Fix `contrib/xml2`'s `xslt_process()` to properly handle the maximum number of parameters (twenty) (Tom)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)
- Update time zone data files to tzdata release 2009l for DST law changes in Bangladesh, Egypt, Jordan, Pakistan, Argentina/San_Luis, Cuba, Jordan (historical correction only), Mauritius, Morocco, Palestine, Syria, Tunisia.

E.96. Release 8.3.7

Release Date: 2009-03-16

This release contains a variety of fixes from 8.3.6. For information about new features in the 8.3 major release, see Section E.103.

E.96.1. Migration to Version 8.3.7

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.5, see Section E.98.

E.96.2. Changes

- Prevent error recursion crashes when encoding conversion fails (Tom)

  This change extends fixes made in the last two minor releases for related failure scenarios. The previous fixes were narrowly tailored for the original problem reports, but we have now recognized that *any* error thrown by an encoding conversion function could potentially lead to infinite recursion while trying to report the error. The solution therefore is to disable translation and encoding conversion and report the plain-ASCII form of any error message, if we find we have gotten into a recursive error reporting situation. (CVE-2009-0922)

- Disallow `CREATE CONVERSION` with the wrong encodings for the specified conversion function (Heikki)

  This prevents one possible scenario for encoding conversion failure. The previous change is a backstop to guard against other kinds of failures in the same area.

- Fix `xpath()` to not modify the path expression unless necessary, and to make a saner attempt at it when necessary (Andrew)

  The SQL standard suggests that `xpath` should work on data that is a document fragment, but libxml doesn't support that, and indeed it's not clear that this is sensible according to the XPath standard. `xpath` attempted to work around this mismatch by modifying both the data and the path expression, but the modification was buggy and could cause valid searches to fail. Now, `xpath` checks whether the data is in fact a well-formed document, and if so invokes libxml with no change to the data or path expression. Otherwise, a different modification method that is somewhat less likely to fail is used.

  > **Note:** The new modification method is still not 100% satisfactory, and it seems likely that no real solution is possible. This patch should therefore be viewed as a band-aid to keep from breaking existing applications unnecessarily. It is likely that PostgreSQL 8.4 will simply reject use of `xpath` on data that is not a well-formed document.

- Fix core dump when `to_char()` is given format codes that are inappropriate for the type of the data argument (Tom)

- Fix possible failure in text search when C locale is used with a multi-byte encoding (Teodor)

  Crashes were possible on platforms where `wchar_t` is narrower than `int`; Windows in particular.

- Fix extreme inefficiency in text search parser's handling of an email-like string containing multiple `@` characters (Heikki)

- Fix planner problem with sub-`SELECT` in the output list of a larger subquery (Tom)

  The known symptom of this bug is a "failed to locate grouping columns" error that is dependent on the datatype involved; but there could be other issues as well.

- Fix decompilation of `CASE WHEN` with an implicit coercion (Tom)

This mistake could lead to Assert failures in an Assert-enabled build, or an "unexpected CASE WHEN clause" error message in other cases, when trying to examine or dump a view.

- Fix possible misassignment of the owner of a TOAST table's rowtype (Tom)

  If `CLUSTER` or a rewriting variant of `ALTER TABLE` were executed by someone other than the table owner, the `pg_type` entry for the table's TOAST table would end up marked as owned by that someone. This caused no immediate problems, since the permissions on the TOAST rowtype aren't examined by any ordinary database operation. However, it could lead to unexpected failures if one later tried to drop the role that issued the command (in 8.1 or 8.2), or "owner of data type appears to be invalid" warnings from pg_dump after having done so (in 8.3).

- Change `UNLISTEN` to exit quickly if the current session has never executed any `LISTEN` command (Tom)

  Most of the time this is not a particularly useful optimization, but since `DISCARD ALL` invokes `UNLISTEN`, the previous coding caused a substantial performance problem for applications that made heavy use of `DISCARD ALL`.

- Fix PL/pgSQL to not treat `INTO` after `INSERT` as an INTO-variables clause anywhere in the string, not only at the start; in particular, don't fail for `INSERT INTO` within `CREATE RULE` (Tom)

- Clean up PL/pgSQL error status variables fully at block exit (Ashesh Vashi and Dave Page)

  This is not a problem for PL/pgSQL itself, but the omission could cause the PL/pgSQL Debugger to crash while examining the state of a function.

- Retry failed calls to `CallNamedPipe()` on Windows (Steve Marshall, Magnus)

  It appears that this function can sometimes fail transiently; we previously treated any failure as a hard error, which could confuse `LISTEN`/`NOTIFY` as well as other operations.

- Add `MUST` (Mauritius Island Summer Time) to the default list of known timezone abbreviations (Xavier Bugaud)

E.97. Release 8.3.6

Release Date: 2009-02-02

This release contains a variety of fixes from 8.3.5. For information about new features in the 8.3 major release, see Section E.103.

E.97.1. Migration to Version 8.3.6

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.5, see Section E.98.

E.97.2. Changes

- Make `DISCARD ALL` release advisory locks, in addition to everything it already did (Tom)

This was decided to be the most appropriate behavior. This could affect existing applications, however.

- Fix whole-index GiST scans to work correctly (Teodor)

  This error could cause rows to be lost if a table is clustered on a GiST index.

- Fix crash of `xmlconcat(NULL)` (Peter)

- Fix possible crash in `ispell` dictionary if high-bit-set characters are used as flags (Teodor)

  This is known to be done by one widely available Norwegian dictionary, and the same condition may exist in others.

- Fix misordering of pg_dump output for composite types (Tom)

  The most likely problem was for user-defined operator classes to be dumped after indexes or views that needed them.

- Improve handling of URLs in `headline()` function (Teodor)

- Improve handling of overlength headlines in `headline()` function (Teodor)

- Prevent possible Assert failure or misconversion if an encoding conversion is created with the wrong conversion function for the specified pair of encodings (Tom, Heikki)

- Fix possible Assert failure if a statement executed in PL/pgSQL is rewritten into another kind of statement, for example if an `INSERT` is rewritten into an `UPDATE` (Heikki)

- Ensure that a snapshot is available to datatype input functions (Tom)

  This primarily affects domains that are declared with `CHECK` constraints involving user-defined stable or immutable functions. Such functions typically fail if no snapshot has been set.

- Make it safer for SPI-using functions to be used within datatype I/O; in particular, to be used in domain check constraints (Tom)

- Avoid unnecessary locking of small tables in `VACUUM` (Heikki)

- Fix a problem that sometimes kept `ALTER TABLE ENABLE/DISABLE RULE` from being recognized by active sessions (Tom)

- Fix a problem that made `UPDATE RETURNING tableoid` return zero instead of the correct OID (Tom)

- Allow functions declared as taking `ANYARRAY` to work on the `pg_statistic` columns of that type (Tom)

  This used to work, but was unintentionally broken in 8.3.

- Fix planner misestimation of selectivity when transitive equality is applied to an outer-join clause (Tom)

  This could result in bad plans for queries like `... from a left join b on a.a1 = b.b1 where a.a1 = 42 ...`

- Improve optimizer's handling of long `IN` lists (Tom)

  This change avoids wasting large amounts of time on such lists when constraint exclusion is enabled.

- Prevent synchronous scan during GIN index build (Tom)

  Because GIN is optimized for inserting tuples in increasing TID order, choosing to use a synchronous scan could slow the build by a factor of three or more.

- Ensure that the contents of a holdable cursor don't depend on the contents of TOAST tables (Tom)

Previously, large field values in a cursor result might be represented as TOAST pointers, which would fail if the referenced table got dropped before the cursor is read, or if the large value is deleted and then vacuumed away. This cannot happen with an ordinary cursor, but it could with a cursor that is held past its creating transaction.

- Fix memory leak when a set-returning function is terminated without reading its whole result (Tom)
- Fix encoding conversion problems in XML functions when the database encoding isn't UTF-8 (Tom)
- Fix `contrib/dblink`'s `dblink_get_result(text,bool)` function (Joe)
- Fix possible garbage output from `contrib/sslinfo` functions (Tom)
- Fix incorrect behavior of `contrib/tsearch2` compatibility trigger when it's fired more than once in a command (Teodor)
- Fix possible mis-signaling in autovacuum (Heikki)
- Support running as a service on Windows 7 beta (Dave and Magnus)
- Fix ecpg's handling of varchar structs (Michael)
- Fix configure script to properly report failure when unable to obtain linkage information for PL/Perl (Andrew)
- Make all documentation reference `pgsql-bugs` and/or `pgsql-hackers` as appropriate, instead of the now-decommissioned `pgsql-ports` and `pgsql-patches` mailing lists (Tom)
- Update time zone data files to tzdata release 2009a (for Kathmandu and historical DST corrections in Switzerland, Cuba)

E.98. Release 8.3.5

Release Date: 2008-11-03

This release contains a variety of fixes from 8.3.4. For information about new features in the 8.3 major release, see Section E.103.

E.98.1. Migration to Version 8.3.5

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.1, see Section E.102. Also, if you were running a previous 8.3.X release, it is recommended to `REINDEX` all GiST indexes after the upgrade.

E.98.2. Changes

- Fix GiST index corruption due to marking the wrong index entry "dead" after a deletion (Teodor)

  This would result in index searches failing to find rows they should have found. Corrupted indexes can be fixed with `REINDEX`.
- Fix backend crash when the client encoding cannot represent a localized error message (Tom)

We have addressed similar issues before, but it would still fail if the "character has no equivalent" message itself couldn't be converted. The fix is to disable localization and send the plain ASCII error message when we detect such a situation.

- Fix possible crash in `bytea`-to-XML mapping (Michael McMaster)
- Fix possible crash when deeply nested functions are invoked from a trigger (Tom)
- Improve optimization of *`expression`* `IN` (*`expression-list`*) queries (Tom, per an idea from Robert Haas)

  Cases in which there are query variables on the right-hand side had been handled less efficiently in 8.2.x and 8.3.x than in prior versions. The fix restores 8.1 behavior for such cases.
- Fix mis-expansion of rule queries when a sub-`SELECT` appears in a function call in `FROM`, a multi-row `VALUES` list, or a `RETURNING` list (Tom)

  The usual symptom of this problem is an "unrecognized node type" error.
- Fix Assert failure during rescan of an `IS NULL` search of a GiST index (Teodor)
- Fix memory leak during rescan of a hashed aggregation plan (Neil)
- Ensure an error is reported when a newly-defined PL/pgSQL trigger function is invoked as a normal function (Tom)
- Force a checkpoint before `CREATE DATABASE` starts to copy files (Heikki)

  This prevents a possible failure if files had recently been deleted in the source database.
- Prevent possible collision of `relfilenode` numbers when moving a table to another tablespace with `ALTER SET TABLESPACE` (Heikki)

  The command tried to re-use the existing filename, instead of picking one that is known unused in the destination directory.
- Fix incorrect text search headline generation when single query item matches first word of text (Sushant Sinha)
- Fix improper display of fractional seconds in interval values when using a non-ISO datestyle in an `--enable-integer-datetimes` build (Ron Mayer)
- Make `ILIKE` compare characters case-insensitively even when they're escaped (Andrew)
- Ensure `DISCARD` is handled properly by statement logging (Tom)
- Fix incorrect logging of last-completed-transaction time during PITR recovery (Tom)
- Ensure `SPI_getvalue` and `SPI_getbinval` behave correctly when the passed tuple and tuple descriptor have different numbers of columns (Tom)

  This situation is normal when a table has had columns added or removed, but these two functions didn't handle it properly. The only likely consequence is an incorrect error indication.
- Mark `SessionReplicationRole` as `PGDLLIMPORT` so it can be used by Slony on Windows (Magnus)
- Fix small memory leak when using libpq's `gsslib` parameter (Magnus)

  The space used by the parameter string was not freed at connection close.
- Ensure libgssapi is linked into libpq if needed (Markus Schaaf)
- Fix ecpg's parsing of `CREATE ROLE` (Michael)
- Fix recent breakage of `pg_ctl restart` (Tom)
- Ensure `pg_control` is opened in binary mode (Itagaki Takahiro)

pg_controldata and pg_resetxlog did this incorrectly, and so could fail on Windows.

- Update time zone data files to tzdata release 2008i (for DST law changes in Argentina, Brazil, Mauritius, Syria)

E.99. Release 8.3.4

Release Date: 2008-09-22

This release contains a variety of fixes from 8.3.3. For information about new features in the 8.3 major release, see Section E.103.

E.99.1. Migration to Version 8.3.4

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.1, see Section E.102.

E.99.2. Changes

- Fix bug in btree WAL recovery code (Heikki)

  Recovery failed if the WAL ended partway through a page split operation.

- Fix potential use of wrong cutoff XID for HOT page pruning (Alvaro)

  This error created a risk of corruption in system catalogs that are consulted by `VACUUM`: dead tuple versions might be removed too soon. The impact of this on actual database operations would be minimal, since the system doesn't follow MVCC rules while examining catalogs, but it might result in transiently wrong output from pg_dump or other client programs.

- Fix potential miscalculation of `datfrozenxid` (Alvaro)

  This error may explain some recent reports of failure to remove old `pg_clog` data.

- Fix incorrect HOT updates after `pg_class` is reindexed (Tom)

  Corruption of `pg_class` could occur if `REINDEX TABLE pg_class` was followed in the same session by an `ALTER TABLE RENAME` or `ALTER TABLE SET SCHEMA` command.

- Fix missed "combo cid" case (Karl Schnaitter)

  This error made rows incorrectly invisible to a transaction in which they had been deleted by multiple subtransactions that all aborted.

- Prevent autovacuum from crashing if the table it's currently checking is deleted at just the wrong time (Alvaro)

- Widen local lock counters from 32 to 64 bits (Tom)

  This responds to reports that the counters could overflow in sufficiently long transactions, leading to unexpected "lock is already held" errors.

- Fix possible duplicate output of tuples during a GiST index scan (Teodor)

- Regenerate foreign key checking queries from scratch when either table is modified (Tom)

  Previously, 8.3 would attempt to replan the query, but would work from previously generated query text. This led to failures if a table or column was renamed.

- Fix missed permissions checks when a view contains a simple `UNION ALL` construct (Heikki)

  Permissions for the referenced tables were checked properly, but not permissions for the view itself.

- Add checks in executor startup to ensure that the tuples produced by an `INSERT` or `UPDATE` will match the target table's current rowtype (Tom)

  This situation is believed to be impossible in 8.3, but it can happen in prior releases, so a check seems prudent.

- Fix possible repeated drops during `DROP OWNED` (Tom)

  This would typically result in strange errors such as "cache lookup failed for relation NNN".

- Fix several memory leaks in XML operations (Kris Jurka, Tom)

- Fix `xmlserialize()` to raise error properly for unacceptable target data type (Tom)

- Fix a couple of places that mis-handled multibyte characters in text search configuration file parsing (Tom)

  Certain characters occurring in configuration files would always cause "invalid byte sequence for encoding" failures.

- Provide file name and line number location for all errors reported in text search configuration files (Tom)

- Fix `AT TIME ZONE` to first try to interpret its timezone argument as a timezone abbreviation, and only try it as a full timezone name if that fails, rather than the other way around as formerly (Tom)

  The timestamp input functions have always resolved ambiguous zone names in this order. Making `AT TIME ZONE` do so as well improves consistency, and fixes a compatibility bug introduced in 8.1: in ambiguous cases we now behave the same as 8.0 and before did, since in the older versions `AT TIME ZONE` accepted *only* abbreviations.

- Fix datetime input functions to correctly detect integer overflow when running on a 64-bit platform (Tom)

- Prevent integer overflows during units conversion when displaying a configuration parameter that has units (Tom)

- Improve performance of writing very long log messages to syslog (Tom)

- Allow spaces in the suffix part of an LDAP URL in `pg_hba.conf` (Tom)

- Fix bug in backwards scanning of a cursor on a `SELECT DISTINCT ON` query (Tom)

- Fix planner bug that could improperly push down `IS NULL` tests below an outer join (Tom)

  This was triggered by occurrence of `IS NULL` tests for the same relation in all arms of an upper `OR` clause.

- Fix planner bug with nested sub-select expressions (Tom)

  If the outer sub-select has no direct dependency on the parent query, but the inner one does, the outer value might not get recalculated for new parent query rows.

- Fix planner to estimate that `GROUP BY` expressions yielding boolean results always result in two groups, regardless of the expressions' contents (Tom)

  This is very substantially more accurate than the regular `GROUP BY` estimate for certain boolean tests like *`col`* `IS NULL`.

- Fix PL/pgSQL to not fail when a `FOR` loop's target variable is a record containing composite-type fields (Tom)
- Fix PL/Tcl to behave correctly with Tcl 8.5, and to be more careful about the encoding of data sent to or from Tcl (Tom)
- Improve performance of `PQescapeBytea()` (Rudolf Leitgeb)
- On Windows, work around a Microsoft bug by preventing libpq from trying to send more than 64kB per system call (Magnus)
- Fix ecpg to handle variables properly in `SET` commands (Michael)
- Improve pg_dump and pg_restore's error reporting after failure to send a SQL command (Tom)
- Fix pg_ctl to properly preserve postmaster command-line arguments across a `restart` (Bruce)
- Fix erroneous WAL file cutoff point calculation in pg_standby (Simon)
- Update time zone data files to tzdata release 2008f (for DST law changes in Argentina, Bahamas, Brazil, Mauritius, Morocco, Pakistan, Palestine, and Paraguay)

E.100. Release 8.3.3

Release Date: 2008-06-12

This release contains one serious and one minor bug fix over 8.3.2. For information about new features in the 8.3 major release, see Section E.103.

E.100.1. Migration to Version 8.3.3

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.1, see Section E.102.

E.100.2. Changes

- Make `pg_get_ruledef()` parenthesize negative constants (Tom)

  Before this fix, a negative constant in a view or rule might be dumped as, say, `-42::integer`, which is subtly incorrect: it should be `(-42)::integer` due to operator precedence rules. Usually this would make little difference, but it could interact with another recent patch to cause PostgreSQL to reject what had been a valid `SELECT DISTINCT` view query. Since this could result in pg_dump output failing to reload, it is being treated as a high-priority fix. The only released versions in which dump output is actually incorrect are 8.3.1 and 8.2.7.

- Make `ALTER AGGREGATE ... OWNER TO` update `pg_shdepend` (Tom)

  This oversight could lead to problems if the aggregate was later involved in a `DROP OWNED` or `REASSIGN OWNED` operation.

E.101. Release 8.3.2

Release Date: never released

This release contains a variety of fixes from 8.3.1. For information about new features in the 8.3 major release, see Section E.103.

E.101.1. Migration to Version 8.3.2

A dump/restore is not required for those running 8.3.X. However, if you are upgrading from a version earlier than 8.3.1, see Section E.102.

E.101.2. Changes

- Fix `ERRORDATA_STACK_SIZE exceeded` crash that occurred on Windows when using UTF-8 database encoding and a different client encoding (Tom)
- Fix incorrect archive truncation point calculation for the `%r` macro in `recovery_command` parameters (Simon)

  This could lead to data loss if a warm-standby script relied on `%r` to decide when to throw away WAL segment files.
- Fix `ALTER TABLE ADD COLUMN ... PRIMARY KEY` so that the new column is correctly checked to see if it's been initialized to all non-nulls (Brendan Jurd)

  Previous versions neglected to check this requirement at all.
- Fix `REASSIGN OWNED` so that it works on procedural languages too (Alvaro)
- Fix problems with `SELECT FOR UPDATE/SHARE` occurring as a subquery in a query with a non-`SELECT` top-level operation (Tom)
- Fix possible `CREATE TABLE` failure when inheriting the "same" constraint from multiple parent relations that inherited that constraint from a common ancestor (Tom)
- Fix `pg_get_ruledef()` to show the alias, if any, attached to the target table of an `UPDATE` or `DELETE` (Tom)
- Restore the pre-8.3 behavior that an out-of-range block number in a TID being used in a TidScan plan results in silently not matching any rows (Tom)

  8.3.0 and 8.3.1 threw an error instead.
- Fix GIN bug that could result in a `too many LWLocks taken` failure (Teodor)
- Fix broken GiST comparison function for `tsquery` (Teodor)
- Fix `tsvector_update_trigger()` and `ts_stat()` to accept domains over the types they expect to work with (Tom)
- Fix failure to support enum data types as foreign keys (Tom)
- Avoid possible crash when decompressing corrupted data (Zdenek Kotala)
- Fix race conditions between delayed unlinks and `DROP DATABASE` (Heikki)

In the worst case this could result in deleting a newly created table in a new database that happened to get the same OID as the recently-dropped one; but of course that is an extremely low-probability scenario.

- Repair two places where SIGTERM exit of a backend could leave corrupted state in shared memory (Tom)

  Neither case is very important if SIGTERM is used to shut down the whole database cluster together, but there was a problem if someone tried to SIGTERM individual backends.

- Fix possible crash due to incorrect plan generated for an `x IN (SELECT y FROM ...)` clause when `x` and `y` have different data types; and make sure the behavior is semantically correct when the conversion from `y`'s type to `x`'s type is lossy (Tom)

- Fix oversight that prevented the planner from substituting known Param values as if they were constants (Tom)

  This mistake partially disabled optimization of unnamed extended-Query statements in 8.3.0 and 8.3.1: in particular the LIKE-to-indexscan optimization would never be applied if the LIKE pattern was passed as a parameter, and constraint exclusion depending on a parameter value didn't work either.

- Fix planner failure when an indexable `MIN` or `MAX` aggregate is used with `DISTINCT` or `ORDER BY` (Tom)

- Fix planner to ensure it never uses a "physical tlist" for a plan node that is feeding a Sort node (Tom)

  This led to the sort having to push around more data than it really needed to, since unused column values were included in the sorted data.

- Avoid unnecessary copying of query strings (Tom)

  This fixes a performance problem introduced in 8.3.0 when a very large number of commands are submitted as a single query string.

- Make `TransactionIdIsCurrentTransactionId()` use binary search instead of linear search when checking child-transaction XIDs (Heikki)

  This fixes some cases in which 8.3.0 was significantly slower than earlier releases.

- Fix conversions between ISO-8859-5 and other encodings to handle Cyrillic "Yo" characters (`ё` and `Ё` with two dots) (Sergey Burladyan)

- Fix several datatype input functions, notably `array_in()`, that were allowing unused bytes in their results to contain uninitialized, unpredictable values (Tom)

  This could lead to failures in which two apparently identical literal values were not seen as equal, resulting in the parser complaining about unmatched `ORDER BY` and `DISTINCT` expressions.

- Fix a corner case in regular-expression substring matching (`substring(`*`string`* `from` *`pattern`*`)`) (Tom)

  The problem occurs when there is a match to the pattern overall but the user has specified a parenthesized subexpression and that subexpression hasn't got a match. An example is `substring('foo' from 'foo(bar)?')`. This should return NULL, since `(bar)` isn't matched, but it was mistakenly returning the whole-pattern match instead (ie, `foo`).

- Prevent cancellation of an auto-vacuum that was launched to prevent XID wraparound (Alvaro)

- Improve `ANALYZE`'s handling of in-doubt tuples (those inserted or deleted by a not-yet-committed transaction) so that the counts it reports to the stats collector are more likely to be correct (Pavan Deolasee)

- Fix initdb to reject a relative path for its `--xlogdir` (`-X`) option (Tom)
- Make psql print tab characters as an appropriate number of spaces, rather than `\x09` as was done in 8.3.0 and 8.3.1 (Bruce)
- Update time zone data files to tzdata release 2008c (for DST law changes in Morocco, Iraq, Choibalsan, Pakistan, Syria, Cuba, and Argentina/San_Luis)
- Add `ECPGget_PGconn()` function to ecpglib (Michael)
- Fix incorrect result from ecpg's `PGTYPEStimestamp_sub()` function (Michael)
- Fix handling of continuation line markers in ecpg (Michael)
- Fix possible crashes in `contrib/cube` functions (Tom)
- Fix core dump in `contrib/xml2`'s `xpath_table()` function when the input query returns a NULL value (Tom)
- Fix `contrib/xml2`'s makefile to not override `CFLAGS`, and make it auto-configure properly for libxslt present or not (Tom)

E.102. Release 8.3.1

Release Date: 2008-03-17

This release contains a variety of fixes from 8.3.0. For information about new features in the 8.3 major release, see Section E.103.

E.102.1. Migration to Version 8.3.1

A dump/restore is not required for those running 8.3.X. However, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the Windows locale issue described below.

E.102.2. Changes

- Fix character string comparison for Windows locales that consider different character combinations as equal (Tom)

  This fix applies only on Windows and only when using UTF-8 database encoding. The same fix was made for all other cases over two years ago, but Windows with UTF-8 uses a separate code path that was not updated. If you are using a locale that considers some non-identical strings as equal, you may need to `REINDEX` to fix existing indexes on textual columns.

- Repair corner-case bugs in `VACUUM FULL` (Tom)

  A potential deadlock between concurrent `VACUUM FULL` operations on different system catalogs was introduced in 8.2. This has now been corrected. 8.3 made this worse because the deadlock could occur within a critical code section, making it a PANIC rather than just ERROR condition.

  Also, a `VACUUM FULL` that failed partway through vacuuming a system catalog could result in cache corruption in concurrent database sessions.

Another `VACUUM FULL` bug introduced in 8.3 could result in a crash or out-of-memory report when dealing with pages containing no live tuples.

- Fix misbehavior of foreign key checks involving `character` or `bit` columns (Tom)

  If the referencing column were of a different but compatible type (for instance `varchar`), the constraint was enforced incorrectly.

- Avoid needless deadlock failures in no-op foreign-key checks (Stephan Szabo, Tom)

- Fix possible core dump when re-planning a prepared query (Tom)

  This bug affected only protocol-level prepare operations, not SQL `PREPARE`, and so tended to be seen only with JDBC, DBI, and other client-side drivers that use prepared statements heavily.

- Fix possible failure when re-planning a query that calls an SPI-using function (Tom)

- Fix failure in row-wise comparisons involving columns of different datatypes (Tom)

- Fix longstanding `LISTEN`/`NOTIFY` race condition (Tom)

  In rare cases a session that had just executed a `LISTEN` might not get a notification, even though one would be expected because the concurrent transaction executing `NOTIFY` was observed to commit later.

  A side effect of the fix is that a transaction that has executed a not-yet-committed `LISTEN` command will not see any row in `pg_listener` for the `LISTEN`, should it choose to look; formerly it would have. This behavior was never documented one way or the other, but it is possible that some applications depend on the old behavior.

- Disallow `LISTEN` and `UNLISTEN` within a prepared transaction (Tom)

  This was formerly allowed but trying to do it had various unpleasant consequences, notably that the originating backend could not exit as long as an `UNLISTEN` remained uncommitted.

- Disallow dropping a temporary table within a prepared transaction (Heikki)

  This was correctly disallowed by 8.1, but the check was inadvertently broken in 8.2 and 8.3.

- Fix rare crash when an error occurs during a query using a hash index (Heikki)

- Fix incorrect comparison of `tsquery` values (Teodor)

- Fix incorrect behavior of `LIKE` with non-ASCII characters in single-byte encodings (Rolf Jentsch)

- Disable `xmlvalidate` (Tom)

  This function should have been removed before 8.3 release, but was inadvertently left in the source code. It poses a small security risk since unprivileged users could use it to read the first few characters of any file accessible to the server.

- Fix memory leaks in certain usages of set-returning functions (Neil)

- Make `encode(`*`bytea`*`, 'escape')` convert all high-bit-set byte values into `\`*`nnn`* octal escape sequences (Tom)

  This is necessary to avoid encoding problems when the database encoding is multi-byte. This change could pose compatibility issues for applications that are expecting specific results from `encode`.

- Fix input of datetime values for February 29 in years BC (Tom)

  The former coding was mistaken about which years were leap years.

- Fix "unrecognized node type" error in some variants of `ALTER OWNER` (Tom)

- Avoid tablespace permissions errors in `CREATE TABLE LIKE INCLUDING INDEXES` (Tom)

- Ensure `pg_stat_activity.waiting` flag is cleared when a lock wait is aborted (Tom)
- Fix handling of process permissions on Windows Vista (Dave, Magnus)

  In particular, this fix allows starting the server as the Administrator user.
- Update time zone data files to tzdata release 2008a (in particular, recent Chile changes); adjust timezone abbreviation `VET` (Venezuela) to mean UTC-4:30, not UTC-4:00 (Tom)
- Fix ecpg problems with arrays (Michael)
- Fix pg_ctl to correctly extract the postmaster's port number from command-line options (Itagaki Takahiro, Tom)

  Previously, `pg_ctl start -w` could try to contact the postmaster on the wrong port, leading to bogus reports of startup failure.
- Use `-fwrapv` to defend against possible misoptimization in recent gcc versions (Tom)

  This is known to be necessary when building PostgreSQL with gcc 4.3 or later.
- Enable building `contrib/uuid-ossp` with MSVC (Hiroshi Saito)

E.103. Release 8.3

Release Date: 2008-02-04

E.103.1. Overview

With significant new functionality and performance enhancements, this release represents a major leap forward for PostgreSQL. This was made possible by a growing community that has dramatically accelerated the pace of development. This release adds the following major features:

- Full text search is integrated into the core database system
- Support for the SQL/XML standard, including new operators and an `XML` data type
- Enumerated data types (`ENUM`)
- Arrays of composite types
- Universally Unique Identifier (`UUID`) data type
- Add control over whether `NULL`s sort first or last
- Updatable cursors
- Server configuration parameters can now be set on a per-function basis
- User-defined types can now have type modifiers
- Automatically re-plan cached queries when table definitions change or statistics are updated
- Numerous improvements in logging and statistics collection
- Support Security Service Provider Interface (SSPI) for authentication on Windows
- Support multiple concurrent autovacuum processes, and other autovacuum improvements
- Allow the whole PostgreSQL distribution to be compiled with Microsoft Visual C++

Major performance improvements are listed below. Most of these enhancements are automatic and do not require user changes or tuning:

- Asynchronous commit delays writes to WAL during transaction commit
- Checkpoint writes can be spread over a longer time period to smooth the I/O spike during each checkpoint
- Heap-Only Tuples (HOT) accelerate space reuse for most `UPDATE`s and `DELETE`s
- Just-in-time background writer strategy improves disk write efficiency
- Using non-persistent transaction IDs for read-only transactions reduces overhead and `VACUUM` requirements
- Per-field and per-row storage overhead has been reduced
- Large sequential scans no longer force out frequently used cached pages
- Concurrent large sequential scans can now share disk reads
- `ORDER BY ... LIMIT` can be done without sorting

The above items are explained in more detail in the sections below.

E.103.2. Migration to Version 8.3

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

E.103.2.1. General

- Non-character data types are no longer automatically cast to `TEXT` (Peter, Tom)

  Previously, if a non-character value was supplied to an operator or function that requires `text` input, it was automatically cast to `text`, for most (though not all) built-in data types. This no longer happens: an explicit cast to `text` is now required for all non-character-string types. For example, these expressions formerly worked:

  ```
  substr(current_date, 1, 4)
  23 LIKE '2%'
  ```

  but will now draw "function does not exist" and "operator does not exist" errors respectively. Use an explicit cast instead:

  ```
  substr(current_date::text, 1, 4)
  23::text LIKE '2%'
  ```

  (Of course, you can use the more verbose `CAST()` syntax too.) The reason for the change is that these automatic casts too often caused surprising behavior. An example is that in previous releases, this expression was accepted but did not do what was expected:

  ```
  current_date < 2017-11-17
  ```

  This is actually comparing a date to an integer, which should be (and now is) rejected — but in the presence of automatic casts both sides were cast to `text` and a textual comparison was done, because the `text < text` operator was able to match the expression when no other < operator could.

Types `char(n)` and `varchar(n)` still cast to `text` automatically. Also, automatic casting to `text` still works for inputs to the concatenation (`||`) operator, so long as least one input is a character-string type.

- Full text search features from `contrib/tsearch2` have been moved into the core server, with some minor syntax changes

  `contrib/tsearch2` now contains a compatibility interface.

- `ARRAY(SELECT ...)`, where the `SELECT` returns no rows, now returns an empty array, rather than NULL (Tom)

- The array type name for a base data type is no longer always the base type's name with an underscore prefix

  The old naming convention is still honored when possible, but application code should no longer depend on it. Instead use the new `pg_type.typarray` column to identify the array data type associated with a given type.

- `ORDER BY ... USING` *`operator`* must now use a less-than or greater-than *`operator`* that is defined in a btree operator class

  This restriction was added to prevent inconsistent results.

- `SET LOCAL` changes now persist until the end of the outermost transaction, unless rolled back (Tom)

  Previously `SET LOCAL`'s effects were lost after subtransaction commit (`RELEASE SAVEPOINT` or exit from a PL/pgSQL exception block).

- Commands rejected in transaction blocks are now also rejected in multiple-statement query strings (Tom)

  For example, `"BEGIN; DROP DATABASE; COMMIT"` will now be rejected even if submitted as a single query message.

- `ROLLBACK` outside a transaction block now issues `NOTICE` instead of `WARNING` (Bruce)

- Prevent `NOTIFY`/`LISTEN`/`UNLISTEN` from accepting schema-qualified names (Bruce)

  Formerly, these commands accepted `schema.relation` but ignored the schema part, which was confusing.

- `ALTER SEQUENCE` no longer affects the sequence's `currval()` state (Tom)

- Foreign keys now must match indexable conditions for cross-data-type references (Tom)

  This improves semantic consistency and helps avoid performance problems.

- Restrict object size functions to users who have reasonable permissions to view such information (Tom)

  For example, `pg_database_size()` now requires `CONNECT` permission, which is granted to everyone by default. `pg_tablespace_size()` requires `CREATE` permission in the tablespace, or is allowed if the tablespace is the default tablespace for the database.

- Remove the undocumented `!!=` (not in) operator (Tom)

  `NOT IN (SELECT ...)` is the proper way to perform this operation.

- Internal hashing functions are now more uniformly-distributed (Tom)

  If application code was computing and storing hash values using internal PostgreSQL hashing functions, the hash values must be regenerated.

- C-code conventions for handling variable-length data values have changed (Greg Stark, Tom)

The new `SET_VARSIZE()` macro *must* be used to set the length of generated `varlena` values. Also, it might be necessary to expand ("de-TOAST") input values in more cases.

- Continuous archiving no longer reports each successful archive operation to the server logs unless `DEBUG` level is used (Simon)

E.103.2.2. Configuration Parameters

- Numerous changes in administrative server parameters

  `bgwriter_lru_percent`, `bgwriter_all_percent`, `bgwriter_all_maxpages`, `stats_start_collector`, and `stats_reset_on_server_start` are removed. `redirect_stderr` is renamed to `logging_collector`. `stats_command_string` is renamed to `track_activities`. `stats_block_level` and `stats_row_level` are merged into `track_counts`. A new boolean configuration parameter, `archive_mode`, controls archiving. Autovacuum's default settings have changed.

- Remove `stats_start_collector` parameter (Tom)

  We now always start the collector process, unless UDP socket creation fails.

- Remove `stats_reset_on_server_start` parameter (Tom)

  This was removed because `pg_stat_reset()` can be used for this purpose.

- Commenting out a parameter in `postgresql.conf` now causes it to revert to its default value (Joachim Wieland)

  Previously, commenting out an entry left the parameter's value unchanged until the next server restart.

E.103.2.3. Character Encodings

- Add more checks for invalidly-encoded data (Andrew)

  This change plugs some holes that existed in literal backslash escape string processing and `COPY` escape processing. Now the de-escaped string is rechecked to see if the result created an invalid multi-byte character.

- Disallow database encodings that are inconsistent with the server's locale setting (Tom)

  On most platforms, `C` locale is the only locale that will work with any database encoding. Other locale settings imply a specific encoding and will misbehave if the database encoding is something different. (Typical symptoms include bogus textual sort order and wrong results from `upper()` or `lower()`.) The server now rejects attempts to create databases that have an incompatible encoding.

- Ensure that `chr()` cannot create invalidly-encoded values (Andrew)

  In UTF8-encoded databases the argument of `chr()` is now treated as a Unicode code point. In other multi-byte encodings `chr()`'s argument must designate a 7-bit ASCII character. Zero is no longer accepted. `ascii()` has been adjusted to match.

- Adjust `convert()` behavior to ensure encoding validity (Andrew)

  The two argument form of `convert()` has been removed. The three argument form now takes a `bytea` first argument and returns a `bytea`. To cover the loss of functionality, three new functions have been added:

  - `convert_from(bytea, name)` returns `text` — converts the first argument from the named encoding to the database encoding
  - `convert_to(text, name)` returns `bytea` — converts the first argument from the database encoding to the named encoding
  - `length(bytea, name)` returns `integer` — gives the length of the first argument in characters in the named encoding

- Remove `convert(argument USING conversion_name)` (Andrew)

  Its behavior did not match the SQL standard.

- Make JOHAB encoding client-only (Tatsuo)

  JOHAB is not safe as a server-side encoding.

E.103.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 8.3 and the previous major release.

E.103.3.1. Performance

- Asynchronous commit delays writes to WAL during transaction commit (Simon)

  This feature dramatically increases performance for short data-modifying transactions. The disadvantage is that because disk writes are delayed, if the database or operating system crashes before data is written to the disk, committed data will be lost. This feature is useful for applications that can accept some data loss. Unlike turning off `fsync`, using asynchronous commit does not put database consistency at risk; the worst case is that after a crash the last few reportedly-committed transactions might not be committed after all. This feature is enabled by turning off `synchronous_commit` (which can be done per-session or per-transaction, if some transactions are critical and others are not). `wal_writer_delay` can be adjusted to control the maximum delay before transactions actually reach disk.

- Checkpoint writes can be spread over a longer time period to smooth the I/O spike during each checkpoint (Itagaki Takahiro and Heikki Linnakangas)

  Previously all modified buffers were forced to disk as quickly as possible during a checkpoint, causing an I/O spike that decreased server performance. This new approach spreads out disk writes during checkpoints, reducing peak I/O usage. (User-requested and shutdown checkpoints are still written as quickly as possible.)

- Heap-Only Tuples (HOT) accelerate space reuse for most `UPDATE`s and `DELETE`s (Pavan Deolasee, with ideas from many others)

  `UPDATE`s and `DELETE`s leave dead tuples behind, as do failed `INSERT`s. Previously only `VACUUM` could reclaim space taken by dead tuples. With HOT dead tuple space can be automatically reclaimed at the time of `INSERT` or `UPDATE` if no changes are made to indexed columns. This allows for more consistent performance. Also, HOT avoids adding duplicate index entries.

- Just-in-time background writer strategy improves disk write efficiency (Greg Smith, Itagaki Takahiro)

This greatly reduces the need for manual tuning of the background writer.

- Per-field and per-row storage overhead have been reduced (Greg Stark, Heikki Linnakangas)

  Variable-length data types with data values less than 128 bytes long will see a storage decrease of 3 to 6 bytes. For example, two adjacent `char(1)` fields now use 4 bytes instead of 16. Row headers are also 4 bytes shorter than before.

- Using non-persistent transaction IDs for read-only transactions reduces overhead and `VACUUM` requirements (Florian Pflug)

  Non-persistent transaction IDs do not increment the global transaction counter. Therefore, they reduce the load on `pg_clog` and increase the time between forced vacuums to prevent transaction ID wraparound. Other performance improvements were also made that should improve concurrency.

- Avoid incrementing the command counter after a read-only command (Tom)

  There was formerly a hard limit of 2^{32} (4 billion) commands per transaction. Now only commands that actually changed the database count, so while this limit still exists, it should be significantly less annoying.

- Create a dedicated WAL writer process to off-load work from backends (Simon)

- Skip unnecessary WAL writes for `CLUSTER` and `COPY` (Simon)

  Unless WAL archiving is enabled, the system now avoids WAL writes for `CLUSTER` and just `fsync()`s the table at the end of the command. It also does the same for `COPY` if the table was created in the same transaction.

- Large sequential scans no longer force out frequently used cached pages (Simon, Heikki, Tom)

- Concurrent large sequential scans can now share disk reads (Jeff Davis)

  This is accomplished by starting the new sequential scan in the middle of the table (where another sequential scan is already in-progress) and wrapping around to the beginning to finish. This can affect the order of returned rows in a query that does not specify `ORDER BY`. The `synchronize_seqscans` configuration parameter can be used to disable this if necessary.

- `ORDER BY ... LIMIT` can be done without sorting (Greg Stark)

  This is done by sequentially scanning the table and tracking just the "top N" candidate rows, rather than performing a full sort of the entire table. This is useful when there is no matching index and the `LIMIT` is not large.

- Put a rate limit on messages sent to the statistics collector by backends (Tom)

  This reduces overhead for short transactions, but might sometimes increase the delay before statistics are tallied.

- Improve hash join performance for cases with many NULLs (Tom)

- Speed up operator lookup for cases with non-exact datatype matches (Tom)

E.103.3.2. Server

- Autovacuum is now enabled by default (Alvaro)

  Several changes were made to eliminate disadvantages of having autovacuum enabled, thereby justifying the change in default. Several other autovacuum parameter defaults were also modified.

- Support multiple concurrent autovacuum processes (Alvaro, Itagaki Takahiro)

This allows multiple vacuums to run concurrently. This prevents vacuuming of a large table from delaying vacuuming of smaller tables.

- Automatically re-plan cached queries when table definitions change or statistics are updated (Tom)

  Previously PL/pgSQL functions that referenced temporary tables would fail if the temporary table was dropped and recreated between function invocations, unless `EXECUTE` was used. This improvement fixes that problem and many related issues.

- Add a `temp_tablespaces` parameter to control the tablespaces for temporary tables and files (Jaime Casanova, Albert Cervera, Bernd Helmle)

  This parameter defines a list of tablespaces to be used. This enables spreading the I/O load across multiple tablespaces. A random tablespace is chosen each time a temporary object is created. Temporary files are no longer stored in per-database `pgsql_tmp/` directories but in per-tablespace directories.

- Place temporary tables' TOAST tables in special schemas named `pg_toast_temp_`*`nnn`* (Tom)

  This allows low-level code to recognize these tables as temporary, which enables various optimizations such as not WAL-logging changes and using local rather than shared buffers for access. This also fixes a bug wherein backends unexpectedly held open file references to temporary TOAST tables.

- Fix problem that a constant flow of new connection requests could indefinitely delay the postmaster from completing a shutdown or a crash restart (Tom)

- Guard against a very-low-probability data loss scenario by preventing re-use of a deleted table's relfilenode until after the next checkpoint (Heikki)

- Fix `CREATE CONSTRAINT TRIGGER` to convert old-style foreign key trigger definitions into regular foreign key constraints (Tom)

  This will ease porting of foreign key constraints carried forward from pre-7.3 databases, if they were never converted using `contrib/adddepend`.

- Fix `DEFAULT NULL` to override inherited defaults (Tom)

  `DEFAULT NULL` was formerly considered a noise phrase, but it should (and now does) override non-null defaults that would otherwise be inherited from a parent table or domain.

- Add new encodings EUC_JIS_2004 and SHIFT_JIS_2004 (Tatsuo)

  These new encodings can be converted to and from UTF-8.

- Change server startup log message from "database system is ready" to "database system is ready to accept connections", and adjust its timing

  The message now appears only when the postmaster is really ready to accept connections.

E.103.3.3. Monitoring

- Add `log_autovacuum_min_duration` parameter to support configurable logging of autovacuum activity (Simon, Alvaro)
- Add `log_lock_waits` parameter to log lock waiting (Simon)
- Add `log_temp_files` parameter to log temporary file usage (Bill Moran)
- Add `log_checkpoints` parameter to improve logging of checkpoints (Greg Smith, Heikki)
- `log_line_prefix` now supports `%s` and `%c` escapes in all processes (Andrew)

Previously these escapes worked only for user sessions, not for background database processes.

- Add `log_restartpoints` to control logging of point-in-time recovery restart points (Simon)
- Last transaction end time is now logged at end of recovery and at each logged restart point (Simon)
- Autovacuum now reports its activity start time in `pg_stat_activity` (Tom)
- Allow server log output in comma-separated value (CSV) format (Arul Shaji, Greg Smith, Andrew Dunstan)

  CSV-format log files can easily be loaded into a database table for subsequent analysis.
- Use PostgreSQL-supplied timezone support for formatting timestamps displayed in the server log (Tom)

  This avoids Windows-specific problems with localized time zone names that are in the wrong encoding. There is a new `log_timezone` parameter that controls the timezone used in log messages, independently of the client-visible `timezone` parameter.
- New system view `pg_stat_bgwriter` displays statistics about background writer activity (Magnus)
- Add new columns for database-wide tuple statistics to `pg_stat_database` (Magnus)
- Add an `xact_start` (transaction start time) column to `pg_stat_activity` (Neil)

  This makes it easier to identify long-running transactions.
- Add `n_live_tuples` and `n_dead_tuples` columns to `pg_stat_all_tables` and related views (Glen Parker)
- Merge `stats_block_level` and `stats_row_level` parameters into a single parameter `track_counts`, which controls all messages sent to the statistics collector process (Tom)
- Rename `stats_command_string` parameter to `track_activities` (Tom)
- Fix statistical counting of live and dead tuples to recognize that committed and aborted transactions have different effects (Tom)

E.103.3.4. Authentication

- Support Security Service Provider Interface (SSPI) for authentication on Windows (Magnus)
- Support GSSAPI authentication (Henry Hotz, Magnus)

  This should be preferred to native Kerberos authentication because GSSAPI is an industry standard.
- Support a global SSL configuration file (Victor Wagner)
- Add `ssl_ciphers` parameter to control accepted SSL ciphers (Victor Wagner)
- Add a Kerberos realm parameter, `krb_realm` (Magnus)

E.103.3.5. Write-Ahead Log (WAL) and Continuous Archiving

- Change the timestamps recorded in transaction WAL records from time_t to TimestampTz representation (Tom)

  This provides sub-second resolution in WAL, which can be useful for point-in-time recovery.
- Reduce WAL disk space needed by warm standby servers (Simon)

This change allows a warm standby server to pass the name of the earliest still-needed WAL file to the recovery script, allowing automatic removal of no-longer-needed WAL files. This is done using `%r` in the `restore_command` parameter of `recovery.conf`.

- New boolean configuration parameter, `archive_mode`, controls archiving (Simon)

  Previously setting `archive_command` to an empty string turned off archiving. Now `archive_mode` turns archiving on and off, independently of `archive_command`. This is useful for stopping archiving temporarily.

E.103.3.6. Queries

- Full text search is integrated into the core database system (Teodor, Oleg)

  Text search has been improved, moved into the core code, and is now installed by default. `contrib/tsearch2` now contains a compatibility interface.

- Add control over whether `NULL`s sort first or last (Teodor, Tom)

  The syntax is `ORDER BY ... NULLS FIRST/LAST`.

- Allow per-column ascending/descending (`ASC`/`DESC`) ordering options for indexes (Teodor, Tom)

  Previously a query using `ORDER BY` with mixed `ASC`/`DESC` specifiers could not fully use an index. Now an index can be fully used in such cases if the index was created with matching `ASC`/`DESC` specifications. `NULL` sort order within an index can be controlled, too.

- Allow `col IS NULL` to use an index (Teodor)

- Updatable cursors (Arul Shaji, Tom)

  This eliminates the need to reference a primary key to `UPDATE` or `DELETE` rows returned by a cursor. The syntax is `UPDATE/DELETE WHERE CURRENT OF`.

- Allow `FOR UPDATE` in cursors (Arul Shaji, Tom)

- Create a general mechanism that supports casts to and from the standard string types (`TEXT`, `VARCHAR`, `CHAR`) for *every* datatype, by invoking the datatype's I/O functions (Tom)

  Previously, such casts were available only for types that had specialized function(s) for the purpose. These new casts are assignment-only in the to-string direction, explicit-only in the other direction, and therefore should create no surprising behavior.

- Allow `UNION` and related constructs to return a domain type, when all inputs are of that domain type (Tom)

  Formerly, the output would be considered to be of the domain's base type.

- Allow limited hashing when using two different data types (Tom)

  This allows hash joins, hash indexes, hashed subplans, and hash aggregation to be used in situations involving cross-data-type comparisons, if the data types have compatible hash functions. Currently, cross-data-type hashing support exists for `smallint`/`integer`/`bigint`, and for `float4`/`float8`.

- Improve optimizer logic for detecting when variables are equal in a `WHERE` clause (Tom)

  This allows mergejoins to work with descending sort orders, and improves recognition of redundant sort columns.

- Improve performance when planning large inheritance trees in cases where most tables are excluded by constraints (Tom)

E.103.3.7. Object Manipulation

- Arrays of composite types (David Fetter, Andrew, Tom)

  In addition to arrays of explicitly-declared composite types, arrays of the rowtypes of regular tables and views are now supported, except for rowtypes of system catalogs, sequences, and TOAST tables.

- Server configuration parameters can now be set on a per-function basis (Tom)

  For example, functions can now set their own `search_path` to prevent unexpected behavior if a different `search_path` exists at run-time. Security definer functions should set `search_path` to avoid security loopholes.

- `CREATE/ALTER FUNCTION` now supports `COST` and `ROWS` options (Tom)

  `COST` allows specification of the cost of a function call. `ROWS` allows specification of the average number or rows returned by a set-returning function. These values are used by the optimizer in choosing the best plan.

- Implement `CREATE TABLE LIKE ... INCLUDING INDEXES` (Trevor Hardcastle, Nikhil Sontakke, Neil)

- Allow `CREATE INDEX CONCURRENTLY` to ignore transactions in other databases (Simon)

- Add `ALTER VIEW ... RENAME TO` and `ALTER SEQUENCE ... RENAME TO` (David Fetter, Neil)

  Previously this could only be done via `ALTER TABLE ... RENAME TO`.

- Make `CREATE/DROP/RENAME DATABASE` wait briefly for conflicting backends to exit before failing (Tom)

  This increases the likelihood that these commands will succeed.

- Allow triggers and rules to be deactivated in groups using a configuration parameter, for replication purposes (Jan)

  This allows replication systems to disable triggers and rewrite rules as a group without modifying the system catalogs directly. The behavior is controlled by `ALTER TABLE` and a new parameter `session_replication_role`.

- User-defined types can now have type modifiers (Teodor, Tom)

  This allows a user-defined type to take a modifier, like `ssnum(7)`. Previously only built-in data types could have modifiers.

E.103.3.8. Utility Commands

- Non-superuser database owners now are able to add trusted procedural languages to their databases by default (Jeremy Drake)

  While this is reasonably safe, some administrators might wish to revoke the privilege. It is controlled by `pg_pltemplate.tmpldbacreate`.

- Allow a session's current parameter setting to be used as the default for future sessions (Tom)

  This is done with `SET ... FROM CURRENT` in `CREATE/ALTER FUNCTION`, `ALTER DATABASE`, or `ALTER ROLE`.

- Implement new commands `DISCARD ALL`, `DISCARD PLANS`, `DISCARD TEMPORARY`, `CLOSE ALL`, and `DEALLOCATE ALL` (Marko Kreen, Neil)

  These commands simplify resetting a database session to its initial state, and are particularly useful for connection-pooling software.

- Make `CLUSTER` MVCC-safe (Heikki Linnakangas)

  Formerly, `CLUSTER` would discard all tuples that were committed dead, even if there were still transactions that should be able to see them under MVCC visibility rules.

- Add new `CLUSTER` syntax: `CLUSTER` *`table`* `USING` *`index`* (Holger Schurig)

  The old `CLUSTER` syntax is still supported, but the new form is considered more logical.

- Fix `EXPLAIN` so it can show complex plans more accurately (Tom)

  References to subplan outputs are now always shown correctly, instead of using `?column`*`N`*`?` for complicated cases.

- Limit the amount of information reported when a user is dropped (Alvaro)

  Previously, dropping (or attempting to drop) a user who owned many objects could result in large `NOTICE` or `ERROR` messages listing all these objects; this caused problems for some client applications. The length of the message is now limited, although a full list is still sent to the server log.

E.103.3.9. Data Types

- Support for the SQL/XML standard, including new operators and an `XML` data type (Nikolay Samokhvalov, Pavel Stehule, Peter)
- Enumerated data types (`ENUM`) (Tom Dunstan)

  This feature provides convenient support for fields that have a small, fixed set of allowed values. An example of creating an `ENUM` type is `CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy')`.

- Universally Unique Identifier (`UUID`) data type (Gevik Babakhani, Neil)

  This closely matches RFC 4122.

- Widen the `MONEY` data type to 64 bits (D'Arcy Cain)

  This greatly increases the range of supported `MONEY` values.

- Fix `float4`/`float8` to handle `Infinity` and `NAN` (Not A Number) consistently (Bruce)

  The code formerly was not consistent about distinguishing `Infinity` from overflow conditions.

- Allow leading and trailing whitespace during input of `boolean` values (Neil)
- Prevent `COPY` from using digits and lowercase letters as delimiters (Tom)

E.103.3.10. Functions

- Add new regular expression functions `regexp_matches()`, `regexp_split_to_array()`, and `regexp_split_to_table()` (Jeremy Drake, Neil)

  These functions provide extraction of regular expression subexpressions and allow splitting a string using a POSIX regular expression.

- Add `lo_truncate()` for large object truncation (Kris Jurka)
- Implement `width_bucket()` for the `float8` data type (Neil)
- Add `pg_stat_clear_snapshot()` to discard statistics snapshots collected during the current transaction (Tom)

  The first request for statistics in a transaction takes a statistics snapshot that does not change during the transaction. This function allows the snapshot to be discarded and a new snapshot loaded during the next statistics query. This is particularly useful for PL/pgSQL functions, which are confined to a single transaction.
- Add `isodow` option to `EXTRACT()` and `date_part()` (Bruce)

  This returns the day of the week, with Sunday as seven. (`dow` returns Sunday as zero.)
- Add `ID` (ISO day of week) and `IDDD` (ISO day of year) format codes for `to_char()`, `to_date()`, and `to_timestamp()` (Brendan Jurd)
- Make `to_timestamp()` and `to_date()` assume `TM` (trim) option for potentially variable-width fields (Bruce)

  This matches Oracle's behavior.
- Fix off-by-one conversion error in `to_date()`/`to_timestamp()` `D` (non-ISO day of week) fields (Bruce)
- Make `setseed()` return void, rather than a useless integer value (Neil)
- Add a hash function for `NUMERIC` (Neil)

  This allows hash indexes and hash-based plans to be used with `NUMERIC` columns.
- Improve efficiency of `LIKE`/`ILIKE`, especially for multi-byte character sets like UTF-8 (Andrew, Itagaki Takahiro)
- Make `currtid()` functions require `SELECT` privileges on the target table (Tom)
- Add several `txid_*()` functions to query active transaction IDs (Jan)

  This is useful for various replication solutions.

E.103.3.11. PL/pgSQL Server-Side Language

- Add scrollable cursor support, including directional control in `FETCH` (Pavel Stehule)
- Allow `IN` as an alternative to `FROM` in PL/pgSQL's `FETCH` statement, for consistency with the backend's `FETCH` command (Pavel Stehule)
- Add `MOVE` to PL/pgSQL (Magnus, Pavel Stehule, Neil)
- Implement `RETURN QUERY` (Pavel Stehule, Neil)

  This adds convenient syntax for PL/pgSQL set-returning functions that want to return the result of a query. `RETURN QUERY` is easier and more efficient than a loop around `RETURN NEXT`.
- Allow function parameter names to be qualified with the function's name (Tom)

  For example, `myfunc.myvar`. This is particularly useful for specifying variables in a query where the variable name might match a column name.
- Make qualification of variables with block labels work properly (Tom)

  Formerly, outer-level block labels could unexpectedly interfere with recognition of inner-level record or row references.

- Tighten requirements for `FOR` loop `STEP` values (Tom)

  Prevent non-positive `STEP` values, and handle loop overflows.

- Improve accuracy when reporting syntax error locations (Tom)

E.103.3.12. Other Server-Side Languages

- Allow type-name arguments to PL/Perl `spi_prepare()` to be data type aliases in addition to names found in `pg_type` (Andrew)
- Allow type-name arguments to PL/Python `plpy.prepare()` to be data type aliases in addition to names found in `pg_type` (Andrew)
- Allow type-name arguments to PL/Tcl `spi_prepare` to be data type aliases in addition to names found in `pg_type` (Andrew)
- Enable PL/PythonU to compile on Python 2.5 (Marko Kreen)
- Support a true PL/Python boolean type in compatible Python versions (Python 2.3 and later) (Marko Kreen)
- Fix PL/Tcl problems with thread-enabled `libtcl` spawning multiple threads within the backend (Steve Marshall, Paul Bayer, Doug Knight)

  This caused all sorts of unpleasantness.

E.103.3.13. psql

- List disabled triggers separately in `\d` output (Brendan Jurd)
- In `\d` patterns, always match `$` literally (Tom)
- Show aggregate return types in `\da` output (Greg Sabino Mullane)
- Add the function's volatility status to the output of `\df+` (Neil)
- Add `\prompt` capability (Chad Wagner)
- Allow `\pset`, `\t`, and `\x` to specify `on` or `off`, rather than just toggling (Chad Wagner)
- Add `\sleep` capability (Jan)
- Enable `\timing` output for `\copy` (Andrew)
- Improve `\timing` resolution on Windows (Itagaki Takahiro)
- Flush `\o` output after each backslash command (Tom)
- Correctly detect and report errors while reading a `-f` input file (Peter)
- Remove `-u` option (this option has long been deprecated) (Tom)

E.103.3.14. pg_dump

- Add `--tablespaces-only` and `--roles-only` options to pg_dumpall (Dave Page)
- Add an output file option to pg_dumpall (Dave Page)

This is primarily useful on Windows, where output redirection of child pg_dump processes does not work.

- Allow pg_dumpall to accept an initial-connection database name rather than the default `template1` (Dave Page)
- In `-n` and `-t` switches, always match `$` literally (Tom)
- Improve performance when a database has thousands of objects (Tom)
- Remove `-u` option (this option has long been deprecated) (Tom)

E.103.3.15. Other Client Applications

- In initdb, allow the location of the `pg_xlog` directory to be specified (Euler Taveira de Oliveira)
- Enable server core dump generation in pg_regress on supported operating systems (Andrew)
- Add a `-t` (timeout) parameter to pg_ctl (Bruce)

  This controls how long pg_ctl will wait when waiting for server startup or shutdown. Formerly the timeout was hard-wired as 60 seconds.
- Add a pg_ctl option to control generation of server core dumps (Andrew)
- Allow Control-C to cancel clusterdb, reindexdb, and vacuumdb (Itagaki Takahiro, Magnus)
- Suppress command tag output for createdb, createuser, dropdb, and dropuser (Peter)

  The `--quiet` option is ignored and will be removed in 8.4. Progress messages when acting on all databases now go to stdout instead of stderr because they are not actually errors.

E.103.3.16. libpq

- Interpret the `dbName` parameter of `PQsetdbLogin()` as a `conninfo` string if it contains an equals sign (Andrew)

  This allows use of `conninfo` strings in client programs that still use `PQsetdbLogin()`.
- Support a global SSL configuration file (Victor Wagner)
- Add environment variable `PGSSLKEY` to control SSL hardware keys (Victor Wagner)
- Add `lo_truncate()` for large object truncation (Kris Jurka)
- Add `PQconnectionNeedsPassword()` that returns true if the server required a password but none was supplied (Joe Conway, Tom)

  If this returns true after a failed connection attempt, a client application should prompt the user for a password. In the past applications have had to check for a specific error message string to decide whether a password is needed; that approach is now deprecated.
- Add `PQconnectionUsedPassword()` that returns true if the supplied password was actually used (Joe Conway, Tom)

  This is useful in some security contexts where it is important to know whether a user-supplied password is actually valid.

E.103.3.17. ecpg

- Use V3 frontend/backend protocol (Michael)

  This adds support for server-side prepared statements.
- Use native threads, instead of pthreads, on Windows (Magnus)
- Improve thread-safety of ecpglib (Itagaki Takahiro)
- Make the ecpg libraries export only necessary API symbols (Michael)

E.103.3.18. Windows Port

- Allow the whole PostgreSQL distribution to be compiled with Microsoft Visual C++ (Magnus and others)

  This allows Windows-based developers to use familiar development and debugging tools. Windows executables made with Visual C++ might also have better stability and performance than those made with other tool sets. The client-only Visual C++ build scripts have been removed.
- Drastically reduce postmaster's memory usage when it has many child processes (Magnus)
- Allow regression tests to be started by an administrative user (Magnus)
- Add native shared memory implementation (Magnus)

E.103.3.19. Server Programming Interface (SPI)

- Add cursor-related functionality in SPI (Pavel Stehule)

  Allow access to the cursor-related planning options, and add `FETCH`/`MOVE` routines.
- Allow execution of cursor commands through `SPI_execute` (Tom)

  The macro `SPI_ERROR_CURSOR` still exists but will never be returned.
- SPI plan pointers are now declared as `SPIPlanPtr` instead of `void *` (Tom)

  This does not break application code, but switching is recommended to help catch simple programming mistakes.

E.103.3.20. Build Options

- Add configure option `--enable-profiling` to enable code profiling (works only with gcc) (Korry Douglas and Nikhil Sontakke)
- Add configure option `--with-system-tzdata` to use the operating system's time zone database (Peter)
- Fix PGXS so extensions can be built against PostgreSQL installations whose pg_config program does not appear first in the `PATH` (Tom)
- Support `gmake draft` when building the SGML documentation (Bruce)

  Unless `draft` is used, the documentation build will now be repeated if necessary to ensure the index is up-to-date.

E.103.3.21. Source Code

- Rename macro DLLIMPORT to PGDLLIMPORT to avoid conflicting with third party includes (like Tcl) that define DLLIMPORT (Magnus)
- Create "operator families" to improve planning of queries involving cross-data-type comparisons (Tom)
- Update GIN extractQuery() API to allow signalling that nothing can satisfy the query (Teodor)
- Move NAMEDATALEN definition from postgres_ext.h to pg_config_manual.h (Peter)
- Provide strlcpy() and strlcat() on all platforms, and replace error-prone uses of strncpy(), strncat(), etc (Peter)
- Create hooks to let an external plugin monitor (or even replace) the planner and create plans for hypothetical situations (Gurjeet Singh, Tom)
- Create a function variable join_search_hook to let plugins override the join search order portion of the planner (Julius Stroffek)
- Add tas() support for Renesas' M32R processor (Kazuhiro Inaoka)
- quote_identifier() and pg_dump no longer quote keywords that are unreserved according to the grammar (Tom)
- Change the on-disk representation of the NUMERIC data type so that the sign_dscale word comes before the weight (Tom)
- Use SYSV semaphores rather than POSIX on Darwin >= 6.0, i.e., OS X 10.2 and up (Chris Marcellino)
- Add acronym and NFS documentation sections (Bruce)
- "Postgres" is now documented as an accepted alias for "PostgreSQL" (Peter)
- Add documentation about preventing database server spoofing when the server is down (Bruce)

E.103.3.22. Contrib

- Move contrib README content into the main PostgreSQL documentation (Albert Cervera i Areny)
- Add contrib/pageinspect module for low-level page inspection (Simon, Heikki)
- Add contrib/pg_standby module for controlling warm standby operation (Simon)
- Add contrib/uuid-ossp module for generating UUID values using the OSSP UUID library (Peter)

  Use configure --with-ossp-uuid to activate. This takes advantage of the new UUID builtin type.
- Add contrib/dict_int, contrib/dict_xsyn, and contrib/test_parser modules to provide sample add-on text search dictionary templates and parsers (Sergey Karpov)
- Allow contrib/pgbench to set the fillfactor (Pavan Deolasee)
- Add timestamps to contrib/pgbench -l (Greg Smith)
- Add usage count statistics to contrib/pgbuffercache (Greg Smith)
- Add GIN support for contrib/hstore (Teodor)
- Add GIN support for contrib/pg_trgm (Guillaume Smet, Teodor)

- Update OS/X startup scripts in `contrib/start-scripts` (Mark Cotner, David Fetter)
- Restrict `pgrowlocks()` and `dblink_get_pkey()` to users who have `SELECT` privilege on the target table (Tom)
- Restrict `contrib/pgstattuple` functions to superusers (Tom)
- `contrib/xml2` is deprecated and planned for removal in 8.4 (Peter)

  The new XML support in core PostgreSQL supersedes this module.

E.104. Release 8.2.23

Release Date: 2011-12-05

This release contains a variety of fixes from 8.2.22. For information about new features in the 8.2 major release, see Section E.127.

This is expected to be the last PostgreSQL release in the 8.2.X series. Users are encouraged to update to a newer release branch soon.

E.104.1. Migration to Version 8.2.23

A dump/restore is not required for those running 8.2.X.

However, a longstanding error was discovered in the definition of the `information_schema.referential_constraints` view. If you rely on correct results from that view, you should replace its definition as explained in the first changelog item below.

Also, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.104.2. Changes

- Fix bugs in `information_schema.referential_constraints` view (Tom Lane)

  This view was being insufficiently careful about matching the foreign-key constraint to the depended-on primary or unique key constraint. That could result in failure to show a foreign key constraint at all, or showing it multiple times, or claiming that it depends on a different constraint than the one it really does.

  Since the view definition is installed by initdb, merely upgrading will not fix the problem. If you need to fix this in an existing installation, you can (as a superuser) drop the `information_schema` schema then re-create it by sourcing *`SHAREDIR`*`/information_schema.sql`. (Run `pg_config --sharedir` if you're uncertain where *`SHAREDIR`* is.) This must be repeated in each database to be fixed.

- Fix TOAST-related data corruption during `CREATE TABLE dest AS SELECT * FROM src` or `INSERT INTO dest SELECT * FROM src` (Tom Lane)

  If a table has been modified by `ALTER TABLE ADD COLUMN`, attempts to copy its data verbatim to another table could produce corrupt results in certain corner cases. The problem can only manifest

in this precise form in 8.4 and later, but we patched earlier versions as well in case there are other code paths that could trigger the same bug.

- Fix race condition during toast table access from stale syscache entries (Tom Lane)

  The typical symptom was transient errors like "missing chunk number 0 for toast value NNNNN in pg_toast_2619", where the cited toast table would always belong to a system catalog.

- Improve locale support in `money` type's input and output (Tom Lane)

  Aside from not supporting all standard `lc_monetary` formatting options, the input and output functions were inconsistent, meaning there were locales in which dumped `money` values could not be re-read.

- Don't let `transform_null_equals` affect `CASE foo WHEN NULL ...` constructs (Heikki Linnakangas)

  `transform_null_equals` is only supposed to affect `foo = NULL` expressions written directly by the user, not equality checks generated internally by this form of `CASE`.

- Change foreign-key trigger creation order to better support self-referential foreign keys (Tom Lane)

  For a cascading foreign key that references its own table, a row update will fire both the `ON UPDATE` trigger and the `CHECK` trigger as one event. The `ON UPDATE` trigger must execute first, else the `CHECK` will check a non-final state of the row and possibly throw an inappropriate error. However, the firing order of these triggers is determined by their names, which generally sort in creation order since the triggers have auto-generated names following the convention "RI_ConstraintTrigger_NNNN". A proper fix would require modifying that convention, which we will do in 9.2, but it seems risky to change it in existing releases. So this patch just changes the creation order of the triggers. Users encountering this type of error should drop and re-create the foreign key constraint to get its triggers into the right order.

- Preserve blank lines within commands in psql's command history (Robert Haas)

  The former behavior could cause problems if an empty line was removed from within a string literal, for example.

- Use the preferred version of xsubpp to build PL/Perl, not necessarily the operating system's main copy (David Wheeler and Alex Hunsaker)

- Honor query cancel interrupts promptly in `pgstatindex()` (Robert Haas)

- Ensure VPATH builds properly install all server header files (Peter Eisentraut)

- Shorten file names reported in verbose error messages (Peter Eisentraut)

  Regular builds have always reported just the name of the C file containing the error message call, but VPATH builds formerly reported an absolute path name.

- Fix interpretation of Windows timezone names for Central America (Tom Lane)

  Map "Central America Standard Time" to `CST6`, not `CST6CDT`, because DST is generally not observed anywhere in Central America.

- Update time zone data files to tzdata release 2011n for DST law changes in Brazil, Cuba, Fiji, Palestine, Russia, and Samoa; also historical corrections for Alaska and British East Africa.

E.105. Release 8.2.22

Release Date: 2011-09-26

This release contains a variety of fixes from 8.2.21. For information about new features in the 8.2 major release, see Section E.127.

The PostgreSQL community will stop releasing updates for the 8.2.X release series in December 2011. Users are encouraged to update to a newer release branch soon.

E.105.1. Migration to Version 8.2.22

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.105.2. Changes

- Fix multiple bugs in GiST index page split processing (Heikki Linnakangas)

  The probability of occurrence was low, but these could lead to index corruption.

- Avoid possibly accessing off the end of memory in `ANALYZE` (Noah Misch)

  This fixes a very-low-probability server crash scenario.

- Fix race condition in relcache init file invalidation (Tom Lane)

  There was a window wherein a new backend process could read a stale init file but miss the inval messages that would tell it the data is stale. The result would be bizarre failures in catalog accesses, typically "could not read block 0 in file ..." later during startup.

- Fix memory leak at end of a GiST index scan (Tom Lane)

  Commands that perform many separate GiST index scans, such as verification of a new GiST-based exclusion constraint on a table already containing many rows, could transiently require large amounts of memory due to this leak.

- Fix performance problem when constructing a large, lossy bitmap (Tom Lane)

- Fix array- and path-creating functions to ensure padding bytes are zeroes (Tom Lane)

  This avoids some situations where the planner will think that semantically-equal constants are not equal, resulting in poor optimization.

- Work around gcc 4.6.0 bug that breaks WAL replay (Tom Lane)

  This could lead to loss of committed transactions after a server crash.

- Fix dump bug for `VALUES` in a view (Tom Lane)

- Disallow `SELECT FOR UPDATE/SHARE` on sequences (Tom Lane)

  This operation doesn't work as expected and can lead to failures.

- Defend against integer overflow when computing size of a hash table (Tom Lane)

- Fix portability bugs in use of credentials control messages for "peer" authentication (Tom Lane)

- Fix typo in `pg_srand48` seed initialization (Andres Freund)

  This led to failure to use all bits of the provided seed. This function is not used on most platforms (only those without `srandom`), and the potential security exposure from a less-random-than-expected seed seems minimal in any case.

- Avoid integer overflow when the sum of `LIMIT` and `OFFSET` values exceeds 2^63 (Heikki Linnakangas)
- Add overflow checks to `int4` and `int8` versions of `generate_series()` (Robert Haas)
- Fix trailing-zero removal in `to_char()` (Marti Raudsepp)

  In a format with `FM` and no digit positions after the decimal point, zeroes to the left of the decimal point could be removed incorrectly.
- Fix `pg_size_pretty()` to avoid overflow for inputs close to 2^63 (Tom Lane)
- Fix psql's counting of script file line numbers during `COPY` from a different file (Tom Lane)
- Fix pg_restore's direct-to-database mode for `standard_conforming_strings` (Tom Lane)

  pg_restore could emit incorrect commands when restoring directly to a database server from an archive file that had been made with `standard_conforming_strings` set to `on`.
- Fix write-past-buffer-end and memory leak in libpq's LDAP service lookup code (Albe Laurenz)
- In libpq, avoid failures when using nonblocking I/O and an SSL connection (Martin Pihlak, Tom Lane)
- Improve libpq's handling of failures during connection startup (Tom Lane)

  In particular, the response to a server report of `fork()` failure during SSL connection startup is now saner.
- Make ecpglib write `double` values with 15 digits precision (Akira Kurosawa)
- Apply upstream fix for blowfish signed-character bug (CVE-2011-2483) (Tom Lane)

  `contrib/pg_crypto`'s blowfish encryption code could give wrong results on platforms where char is signed (which is most), leading to encrypted passwords being weaker than they should be.
- Fix memory leak in `contrib/seg` (Heikki Linnakangas)
- Fix `pgstatindex()` to give consistent results for empty indexes (Tom Lane)
- Allow building with perl 5.14 (Alex Hunsaker)
- Update configure script's method for probing existence of system functions (Tom Lane)

  The version of autoconf we used in 8.3 and 8.2 could be fooled by compilers that perform link-time optimization.
- Fix assorted issues with build and install file paths containing spaces (Tom Lane)
- Update time zone data files to tzdata release 2011i for DST law changes in Canada, Egypt, Russia, Samoa, and South Sudan.

E.106. Release 8.2.21

Release Date: 2011-04-18

This release contains a variety of fixes from 8.2.20. For information about new features in the 8.2 major release, see Section E.127.

E.106.1. Migration to Version 8.2.21

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.106.2. Changes

- Avoid potential deadlock during catalog cache initialization (Nikhil Sontakke)

  In some cases the cache loading code would acquire share lock on a system index before locking the index's catalog. This could deadlock against processes trying to acquire exclusive locks in the other, more standard order.

- Fix dangling-pointer problem in `BEFORE ROW UPDATE` trigger handling when there was a concurrent update to the target tuple (Tom Lane)

  This bug has been observed to result in intermittent "cannot extract system attribute from virtual tuple" failures while trying to do `UPDATE RETURNING ctid`. There is a very small probability of more serious errors, such as generating incorrect index entries for the updated tuple.

- Disallow `DROP TABLE` when there are pending deferred trigger events for the table (Tom Lane)

  Formerly the `DROP` would go through, leading to "could not open relation with OID nnn" errors when the triggers were eventually fired.

- Fix PL/Python memory leak involving array slices (Daniel Popowich)

- Fix pg_restore to cope with long lines (over 1KB) in TOC files (Tom Lane)

- Put in more safeguards against crashing due to division-by-zero with overly enthusiastic compiler optimization (Aurelien Jarno)

- Support use of dlopen() in FreeBSD and OpenBSD on MIPS (Tom Lane)

  There was a hard-wired assumption that this system function was not available on MIPS hardware on these systems. Use a compile-time test instead, since more recent versions have it.

- Fix compilation failures on HP-UX (Heikki Linnakangas)

- Fix path separator used by pg_regress on Cygwin (Andrew Dunstan)

- Update time zone data files to tzdata release 2011f for DST law changes in Chile, Cuba, Falkland Islands, Morocco, Samoa, and Turkey; also historical corrections for South Australia, Alaska, and Hawaii.

E.107. Release 8.2.20

Release Date: 2011-01-31

This release contains a variety of fixes from 8.2.19. For information about new features in the 8.2 major release, see Section E.127.

E.107.1. Migration to Version 8.2.20

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.107.2. Changes

- Avoid failures when `EXPLAIN` tries to display a simple-form `CASE` expression (Tom Lane)

  If the `CASE`'s test expression was a constant, the planner could simplify the `CASE` into a form that confused the expression-display code, resulting in "unexpected CASE WHEN clause" errors.

- Fix assignment to an array slice that is before the existing range of subscripts (Tom Lane)

  If there was a gap between the newly added subscripts and the first pre-existing subscript, the code miscalculated how many entries needed to be copied from the old array's null bitmap, potentially leading to data corruption or crash.

- Avoid unexpected conversion overflow in planner for very distant date values (Tom Lane)

  The `date` type supports a wider range of dates than can be represented by the `timestamp` types, but the planner assumed it could always convert a date to timestamp with impunity.

- Fix pg_restore's text output for large objects (BLOBs) when `standard_conforming_strings` is on (Tom Lane)

  Although restoring directly to a database worked correctly, string escaping was incorrect if pg_restore was asked for SQL text output and `standard_conforming_strings` had been enabled in the source database.

- Fix erroneous parsing of `tsquery` values containing `... & !(subexpression) | ...` (Tom Lane)

  Queries containing this combination of operators were not executed correctly. The same error existed in `contrib/intarray`'s `query_int` type and `contrib/ltree`'s `ltxtquery` type.

- Fix buffer overrun in `contrib/intarray`'s input function for the `query_int` type (Apple)

  This bug is a security risk since the function's return address could be overwritten. Thanks to Apple Inc's security team for reporting this issue and supplying the fix. (CVE-2010-4015)

- Fix bug in `contrib/seg`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `seg` column. If you have such an index, consider `REINDEX`ing it after installing this update. (This is identical to the bug that was fixed in `contrib/cube` in the previous update.)

E.108. Release 8.2.19

Release Date: 2010-12-16

This release contains a variety of fixes from 8.2.18. For information about new features in the 8.2 major release, see Section E.127.

E.108.1. Migration to Version 8.2.19

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.108.2. Changes

- Force the default `wal_sync_method` to be `fdatasync` on Linux (Tom Lane, Marti Raudsepp)

  The default on Linux has actually been `fdatasync` for many years, but recent kernel changes caused PostgreSQL to choose `open_datasync` instead. This choice did not result in any performance improvement, and caused outright failures on certain filesystems, notably `ext4` with the `data=journal` mount option.

- Fix assorted bugs in WAL replay logic for GIN indexes (Tom Lane)

  This could result in "bad buffer id: 0" failures or corruption of index contents during replication.

- Fix recovery from base backup when the starting checkpoint WAL record is not in the same WAL segment as its redo point (Jeff Davis)

- Add support for detecting register-stack overrun on `IA64` (Tom Lane)

  The `IA64` architecture has two hardware stacks. Full prevention of stack-overrun failures requires checking both.

- Add a check for stack overflow in `copyObject()` (Tom Lane)

  Certain code paths could crash due to stack overflow given a sufficiently complex query.

- Fix detection of page splits in temporary GiST indexes (Heikki Linnakangas)

  It is possible to have a "concurrent" page split in a temporary index, if for example there is an open cursor scanning the index when an insertion is done. GiST failed to detect this case and hence could deliver wrong results when execution of the cursor continued.

- Avoid memory leakage while `ANALYZE`'ing complex index expressions (Tom Lane)

- Ensure an index that uses a whole-row Var still depends on its table (Tom Lane)

  An index declared like `create index i on t (foo(t.*))` would not automatically get dropped when its table was dropped.

- Do not "inline" a SQL function with multiple `OUT` parameters (Tom Lane)

  This avoids a possible crash due to loss of information about the expected result rowtype.

- Behave correctly if `ORDER BY`, `LIMIT`, `FOR UPDATE`, or `WITH` is attached to the `VALUES` part of `INSERT ... VALUES` (Tom Lane)

- Fix constant-folding of `COALESCE()` expressions (Tom Lane)

  The planner would sometimes attempt to evaluate sub-expressions that in fact could never be reached, possibly leading to unexpected errors.

- Add print functionality for `InhRelation` nodes (Tom Lane)

  This avoids a failure when `debug_print_parse` is enabled and certain types of query are executed.

- Fix incorrect calculation of distance from a point to a horizontal line segment (Tom Lane)

  This bug affected several different geometric distance-measurement operators.

- Fix PL/pgSQL's handling of "simple" expressions to not fail in recursion or error-recovery cases (Tom Lane)
- Fix PL/Python's handling of set-returning functions (Jan Urbanski)

  Attempts to call SPI functions within the iterator generating a set result would fail.
- Fix bug in `contrib/cube`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `cube` column. If you have such an index, consider `REINDEX`ing it after installing this update.
- Don't emit "identifier will be truncated" notices in `contrib/dblink` except when creating new connections (Itagaki Takahiro)
- Fix potential coredump on missing public key in `contrib/pgcrypto` (Marti Raudsepp)
- Fix memory leak in `contrib/xml2`'s XPath query functions (Tom Lane)
- Update time zone data files to tzdata release 2010o for DST law changes in Fiji and Samoa; also historical corrections for Hong Kong.

E.109. Release 8.2.18

Release Date: 2010-10-04

This release contains a variety of fixes from 8.2.17. For information about new features in the 8.2 major release, see Section E.127.

E.109.1. Migration to Version 8.2.18

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.109.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)
- Fix Windows shared-memory allocation code (Tsutomu Yamada, Magnus Hagander)

  This bug led to the often-reported "could not reattach to shared memory" error message. This is a back-patch of a fix that was applied to newer branches some time ago.
- Treat exit code 128 (`ERROR_WAIT_NO_CHILDREN`) as non-fatal on Windows (Magnus Hagander)

  Under high load, Windows processes will sometimes fail at startup with this error code. Formerly the postmaster treated this as a panic condition and restarted the whole database, but that seems to be an overreaction.
- Fix possible duplicate scans of `UNION ALL` member relations (Tom Lane)
- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.
- Reduce PANIC to ERROR in some occasionally-reported btree failure cases, and provide additional detail in the resulting error messages (Tom Lane)

  This should improve the system's robustness with corrupted indexes.
- Prevent show_session_authorization() from crashing within autovacuum processes (Tom Lane)
- Defend against functions returning setof record where not all the returned rows are actually of the same rowtype (Tom Lane)
- Fix possible failure when hashing a pass-by-reference function result (Tao Ma, Tom Lane)
- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

  This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.
- Avoid recursion while assigning XIDs to heavily-nested subtransactions (Andres Freund, Robert Haas)

  The original coding could result in a crash if there was limited stack space.
- Fix `log_line_prefix`'s `%i` escape, which could produce junk early in backend startup (Tom Lane)
- Fix possible data corruption in `ALTER TABLE ... SET TABLESPACE` when archiving is enabled (Jeff Davis)
- Allow `CREATE DATABASE` and `ALTER DATABASE ... SET TABLESPACE` to be interrupted by query-cancel (Guillaume Lelarge)
- In PL/Python, defend against null pointer results from `PyCObject_AsVoidPtr` and `PyCObject_FromVoidPtr` (Peter Eisentraut)
- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)

- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)
- Fix `contrib/dblink` to handle connection names longer than 62 bytes correctly (Itagaki Takahiro)
- Add `hstore(text, text)` function to `contrib/hstore` (Robert Haas)

  This function is the recommended substitute for the now-deprecated => operator. It was back-patched so that future-proofed code can be used with older server versions. Note that the patch will be effective only after `contrib/hstore` is installed or reinstalled in a particular database. Users might prefer to execute the `CREATE FUNCTION` command by hand, instead.
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)
- Update time zone data files to tzdata release 2010l for DST law changes in Egypt and Palestine; also historical corrections for Finland.

  This change also adds new names for two Micronesian timezones: Pacific/Chuuk is now preferred over Pacific/Truk (and the preferred abbreviation is CHUT not TRUT) and Pacific/Pohnpei is preferred over Pacific/Ponape.
- Make Windows' "N. Central Asia Standard Time" timezone map to Asia/Novosibirsk, not Asia/Almaty (Magnus Hagander)

  Microsoft changed the DST behavior of this zone in the timezone update from KB976098. Asia/Novosibirsk is a better match to its new behavior.

E.110. Release 8.2.17

Release Date: 2010-05-17

This release contains a variety of fixes from 8.2.16. For information about new features in the 8.2 major release, see Section E.127.

E.110.1. Migration to Version 8.2.17

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.110.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b`

variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Fix possible crash if a cache reset message is received during rebuild of a relcache entry (Heikki)

  This error was introduced in 8.2.16 while fixing a related failure.

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

  Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

  In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)

- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)

- Prevent infinite recursion in psql when expanding a variable that refers to itself (Tom)

- Fix psql's `\copy` to not add spaces around a dot within `\copy (select ...)` (Tom)

  Addition of spaces around the decimal point in a numeric literal would result in a syntax error.

- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)

- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.

- Avoid possible crashes in syslogger process on Windows (Heikki)

- Deal more robustly with incomplete time zone information in the Windows registry (Magnus)

- Update the set of known Windows time zone names (Magnus)

- Update time zone data files to tzdata release 2010j for DST law changes in Argentina, Australian Antarctic, Bangladesh, Mexico, Morocco, Pakistan, Palestine, Russia, Syria, Tunisia; also historical corrections for Taiwan.

  Also, add `PKST` (Pakistan Summer Time) to the default set of timezone abbreviations.

E.111. Release 8.2.16

Release Date: 2010-03-15

This release contains a variety of fixes from 8.2.15. For information about new features in the 8.2 major release, see Section E.127.

E.111.1. Migration to Version 8.2.16

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.111.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.
- Fix possible deadlock during backend startup (Tom)
- Fix possible crashes due to not handling errors during relcache reload cleanly (Tom)
- Fix possible crashes when trying to recover from a failure in subtransaction start (Tom)
- Fix server memory leak associated with use of savepoints and a client encoding different from server's encoding (Tom)
- Fix incorrect WAL data emitted during end-of-recovery cleanup of a GIST index page split (Yoichi Hirai)

  This would result in index corruption, or even more likely an error during WAL replay, if we were unlucky enough to crash during end-of-recovery cleanup after having completed an incomplete GIST insertion.
- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).
- Fix integer-to-bit-string conversions to handle the first fractional byte correctly when the output bit width is wider than the given integer by something other than a multiple of 8 bits (Tom)
- Fix some cases of pathologically slow regular expression matching (Tom)
- Fix the `STOP WAL LOCATION` entry in backup history files to report the next WAL segment's name when the end location is exactly at a segment boundary (Itagaki Takahiro)
- Fix some more cases of temporary-file leakage (Heikki)

  This corrects a problem introduced in the previous minor release. One case that failed is when a plpgsql function returning set is called within another function's exception handler.

- Improve constraint exclusion processing of boolean-variable cases, in particular make it possible to exclude a partition that has a "bool_column = false" constraint (Tom)
- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.
- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)
- Fix possible infinite loop if `SSL_read` or `SSL_write` fails without setting `errno` (Tom)

  This is reportedly possible with some Windows versions of openssl.
- Fix psql's `numericlocale` option to not format strings it shouldn't in latex and troff output formats (Heikki)
- Make psql return the correct exit status (3) when `ON_ERROR_STOP` and `--single-transaction` are both specified and an error occurs during the implied `COMMIT` (Bruce)
- Fix plpgsql failure in one case where a composite column is set to NULL (Tom)
- Fix possible failure when calling PL/Perl functions from PL/PerlU or vice versa (Tim Bunce)
- Add `volatile` markings in PL/Python to avoid possible compiler-specific misbehavior (Zdenek Kotala)
- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

  The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.
- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)
- Fix assorted crashes in `contrib/xml2` caused by sloppy memory management (Tom)
- Make building of `contrib/xml2` more robust on Windows (Andrew)
- Fix race condition in Windows signal handling (Radu Ilie)

  One known symptom of this bug is that rows in `pg_listener` could be dropped under heavy load.
- Update time zone data files to tzdata release 2010e for DST law changes in Bangladesh, Chile, Fiji, Mexico, Paraguay, Samoa.

E.112. Release 8.2.15

Release Date: 2009-12-14

This release contains a variety of fixes from 8.2.14. For information about new features in the 8.2 major release, see Section E.127.

E.112.1. Migration to Version 8.2.15

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.14, see Section E.113.

E.112.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).

- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).

- Fix possible crash during backend-startup-time cache initialization (Tom)

- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.

- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.

- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)

- Ensure that shared tuple-level locks held by prepared transactions are not ignored (Heikki)

- Fix premature drop of temporary files used for a cursor that is accessed within a subtransaction (Heikki)

- Fix incorrect logic for GiST index page splits, when the split depends on a non-first column of the index (Paul Ramsey)

- Don't error out if recycling or removing an old WAL file fails at the end of checkpoint (Heikki)

  It's better to treat the problem as non-fatal and allow the checkpoint to complete. Future checkpoints will retry the removal. Such problems are not expected in normal operation, but have been seen to be caused by misdesigned Windows anti-virus and backup software.

- Ensure WAL files aren't repeatedly archived on Windows (Heikki)

  This is another symptom that could happen if some other process interfered with deletion of a no-longer-needed file.

- Fix PAM password processing to be more robust (Tom)

  The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.

- Fix processing of ownership dependencies during `CREATE OR REPLACE FUNCTION` (Tom)

- Fix bug with calling `plperl` from `plperlu` or vice versa (Tom)

  An error exit from the inner function could result in crashes due to failure to re-select the correct Perl interpreter for the outer function.

- Fix session-lifespan memory leak when a PL/Perl function is redefined (Tom)
- Ensure that Perl arrays are properly converted to PostgreSQL arrays when returned by a set-returning PL/Perl function (Andrew Dunstan, Abhijit Menon-Sen)

  This worked correctly already for non-set-returning functions.
- Fix rare crash in exception processing in PL/Python (Peter)
- Ensure psql's flex module is compiled with the correct system header definitions (Tom)

  This fixes build failures on platforms where `--enable-largefile` causes incompatible changes in the generated code.
- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)
- Update the timezone abbreviation files to match current reality (Joachim Wieland)

  This includes adding `IDT` and `SGT` to the default timezone abbreviation set.
- Update time zone data files to tzdata release 2009s for DST law changes in Antarctica, Argentina, Bangladesh, Fiji, Novokuznetsk, Pakistan, Palestine, Samoa, Syria; also historical corrections for Hong Kong.

E.113. Release 8.2.14

Release Date: 2009-09-09

This release contains a variety of fixes from 8.2.13. For information about new features in the 8.2 major release, see Section E.127.

E.113.1. Migration to Version 8.2.14

A dump/restore is not required for those running 8.2.X. However, if you have any hash indexes on `interval` columns, you must `REINDEX` them after updating to 8.2.14. Also, if you are upgrading from a version earlier than 8.2.11, see Section E.116.

E.113.2. Changes

- Force WAL segment switch during `pg_start_backup()` (Heikki)

  This avoids corner cases that could render a base backup unusable.
- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

  This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)
- Make `LOAD` of an already-loaded loadable module into a no-op (Tom)

Formerly, `LOAD` would attempt to unload and re-load the module, but this is unsafe and not all that useful.

- Disallow empty passwords during LDAP authentication (Magnus)
- Fix handling of sub-SELECTs appearing in the arguments of an outer-level aggregate function (Tom)
- Fix bugs associated with fetching a whole-row value from the output of a Sort or Materialize plan node (Tom)
- Revert planner change that disabled partial-index and constraint exclusion optimizations when there were more than 100 clauses in an AND or OR list (Tom)
- Fix hash calculation for data type `interval` (Tom)

  This corrects wrong results for hash joins on interval values. It also changes the contents of hash indexes on interval columns. If you have any such indexes, you must `REINDEX` them after updating.
- Treat `to_char(..., 'TH')` as an uppercase ordinal suffix with `'HH'/'HH12'` (Heikki)

  It was previously handled as `'th'` (lowercase).
- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Fix calculation of distance between a point and a line segment (Tom)

  This led to incorrect results from a number of geometric operators.
- Fix `money` data type to work in locales where currency amounts have no fractional digits, e.g. Japan (Itagaki Takahiro)
- Properly round datetime input like `00:12:57.9999999999999999999999999999` (Tom)
- Fix poor choice of page split point in GiST R-tree operator classes (Teodor)
- Avoid performance degradation in bulk inserts into GIN indexes when the input values are (nearly) in sorted order (Tom)
- Correctly enforce NOT NULL domain constraints in some contexts in PL/pgSQL (Tom)
- Fix portability issues in plperl initialization (Andrew Dunstan)
- Fix pg_ctl to not go into an infinite loop if `postgresql.conf` is empty (Jeff Davis)
- Make `contrib/hstore` throw an error when a key or value is too long to fit in its data structure, rather than silently truncating it (Andrew Gierth)
- Fix `contrib/xml2`'s `xslt_process()` to properly handle the maximum number of parameters (twenty) (Tom)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)
- Update time zone data files to tzdata release 2009l for DST law changes in Bangladesh, Egypt, Jordan, Pakistan, Argentina/San_Luis, Cuba, Jordan (historical correction only), Mauritius, Morocco, Palestine, Syria, Tunisia.

E.114. Release 8.2.13

Release Date: 2009-03-16

This release contains a variety of fixes from 8.2.12. For information about new features in the 8.2 major release, see Section E.127.

E.114.1. Migration to Version 8.2.13

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.11, see Section E.116.

E.114.2. Changes

- Prevent error recursion crashes when encoding conversion fails (Tom)

  This change extends fixes made in the last two minor releases for related failure scenarios. The previous fixes were narrowly tailored for the original problem reports, but we have now recognized that *any* error thrown by an encoding conversion function could potentially lead to infinite recursion while trying to report the error. The solution therefore is to disable translation and encoding conversion and report the plain-ASCII form of any error message, if we find we have gotten into a recursive error reporting situation. (CVE-2009-0922)

- Disallow `CREATE CONVERSION` with the wrong encodings for the specified conversion function (Heikki)

  This prevents one possible scenario for encoding conversion failure. The previous change is a backstop to guard against other kinds of failures in the same area.

- Fix core dump when `to_char()` is given format codes that are inappropriate for the type of the data argument (Tom)

- Fix possible failure in `contrib/tsearch2` when C locale is used with a multi-byte encoding (Teodor)

  Crashes were possible on platforms where `wchar_t` is narrower than `int`; Windows in particular.

- Fix extreme inefficiency in `contrib/tsearch2` parser's handling of an email-like string containing multiple `@` characters (Heikki)

- Fix decompilation of `CASE WHEN` with an implicit coercion (Tom)

  This mistake could lead to Assert failures in an Assert-enabled build, or an "unexpected CASE WHEN clause" error message in other cases, when trying to examine or dump a view.

- Fix possible misassignment of the owner of a TOAST table's rowtype (Tom)

  If `CLUSTER` or a rewriting variant of `ALTER TABLE` were executed by someone other than the table owner, the `pg_type` entry for the table's TOAST table would end up marked as owned by that someone. This caused no immediate problems, since the permissions on the TOAST rowtype aren't examined by any ordinary database operation. However, it could lead to unexpected failures if one later tried to drop the role that issued the command (in 8.1 or 8.2), or "owner of data type appears to be invalid" warnings from pg_dump after having done so (in 8.3).

- Fix PL/pgSQL to not treat `INTO` after `INSERT` as an INTO-variables clause anywhere in the string, not only at the start; in particular, don't fail for `INSERT INTO` within `CREATE RULE` (Tom)
- Clean up PL/pgSQL error status variables fully at block exit (Ashesh Vashi and Dave Page)

  This is not a problem for PL/pgSQL itself, but the omission could cause the PL/pgSQL Debugger to crash while examining the state of a function.
- Retry failed calls to `CallNamedPipe()` on Windows (Steve Marshall, Magnus)

  It appears that this function can sometimes fail transiently; we previously treated any failure as a hard error, which could confuse `LISTEN`/`NOTIFY` as well as other operations.
- Add `MUST` (Mauritius Island Summer Time) to the default list of known timezone abbreviations (Xavier Bugaud)

E.115. Release 8.2.12

Release Date: 2009-02-02

This release contains a variety of fixes from 8.2.11. For information about new features in the 8.2 major release, see Section E.127.

E.115.1. Migration to Version 8.2.12

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.11, see Section E.116.

E.115.2. Changes

- Improve handling of URLs in `headline()` function (Teodor)
- Improve handling of overlength headlines in `headline()` function (Teodor)
- Prevent possible Assert failure or misconversion if an encoding conversion is created with the wrong conversion function for the specified pair of encodings (Tom, Heikki)
- Fix possible Assert failure if a statement executed in PL/pgSQL is rewritten into another kind of statement, for example if an `INSERT` is rewritten into an `UPDATE` (Heikki)
- Ensure that a snapshot is available to datatype input functions (Tom)

  This primarily affects domains that are declared with `CHECK` constraints involving user-defined stable or immutable functions. Such functions typically fail if no snapshot has been set.
- Make it safer for SPI-using functions to be used within datatype I/O; in particular, to be used in domain check constraints (Tom)
- Avoid unnecessary locking of small tables in `VACUUM` (Heikki)
- Fix a problem that made `UPDATE RETURNING tableoid` return zero instead of the correct OID (Tom)

- Fix planner misestimation of selectivity when transitive equality is applied to an outer-join clause (Tom)

  This could result in bad plans for queries like `... from a left join b on a.a1 = b.b1 where a.a1 = 42 ...`

- Improve optimizer's handling of long `IN` lists (Tom)

  This change avoids wasting large amounts of time on such lists when constraint exclusion is enabled.

- Ensure that the contents of a holdable cursor don't depend on the contents of TOAST tables (Tom)

  Previously, large field values in a cursor result might be represented as TOAST pointers, which would fail if the referenced table got dropped before the cursor is read, or if the large value is deleted and then vacuumed away. This cannot happen with an ordinary cursor, but it could with a cursor that is held past its creating transaction.

- Fix memory leak when a set-returning function is terminated without reading its whole result (Tom)

- Fix `contrib/dblink`'s `dblink_get_result(text,bool)` function (Joe)

- Fix possible garbage output from `contrib/sslinfo` functions (Tom)

- Fix configure script to properly report failure when unable to obtain linkage information for PL/Perl (Andrew)

- Make all documentation reference `pgsql-bugs` and/or `pgsql-hackers` as appropriate, instead of the now-decommissioned `pgsql-ports` and `pgsql-patches` mailing lists (Tom)

- Update time zone data files to tzdata release 2009a (for Kathmandu and historical DST corrections in Switzerland, Cuba)

E.116. Release 8.2.11

Release Date: 2008-11-03

This release contains a variety of fixes from 8.2.10. For information about new features in the 8.2 major release, see Section E.127.

E.116.1. Migration to Version 8.2.11

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.7, see Section E.120. Also, if you were running a previous 8.2.X release, it is recommended to `REINDEX` all GiST indexes after the upgrade.

E.116.2. Changes

- Fix GiST index corruption due to marking the wrong index entry "dead" after a deletion (Teodor)

  This would result in index searches failing to find rows they should have found. Corrupted indexes can be fixed with `REINDEX`.

- Fix backend crash when the client encoding cannot represent a localized error message (Tom)

  We have addressed similar issues before, but it would still fail if the "character has no equivalent" message itself couldn't be converted. The fix is to disable localization and send the plain ASCII error message when we detect such a situation.

- Fix possible crash when deeply nested functions are invoked from a trigger (Tom)

- Improve optimization of *expression* IN (*expression-list*) queries (Tom, per an idea from Robert Haas)

  Cases in which there are query variables on the right-hand side had been handled less efficiently in 8.2.x and 8.3.x than in prior versions. The fix restores 8.1 behavior for such cases.

- Fix mis-expansion of rule queries when a sub-SELECT appears in a function call in FROM, a multi-row VALUES list, or a RETURNING list (Tom)

  The usual symptom of this problem is an "unrecognized node type" error.

- Fix memory leak during rescan of a hashed aggregation plan (Neil)

- Ensure an error is reported when a newly-defined PL/pgSQL trigger function is invoked as a normal function (Tom)

- Prevent possible collision of relfilenode numbers when moving a table to another tablespace with ALTER SET TABLESPACE (Heikki)

  The command tried to re-use the existing filename, instead of picking one that is known unused in the destination directory.

- Fix incorrect tsearch2 headline generation when single query item matches first word of text (Sushant Sinha)

- Fix improper display of fractional seconds in interval values when using a non-ISO datestyle in an --enable-integer-datetimes build (Ron Mayer)

- Ensure SPI_getvalue and SPI_getbinval behave correctly when the passed tuple and tuple descriptor have different numbers of columns (Tom)

  This situation is normal when a table has had columns added or removed, but these two functions didn't handle it properly. The only likely consequence is an incorrect error indication.

- Fix ecpg's parsing of CREATE ROLE (Michael)

- Fix recent breakage of pg_ctl restart (Tom)

- Ensure pg_control is opened in binary mode (Itagaki Takahiro)

  pg_controldata and pg_resetxlog did this incorrectly, and so could fail on Windows.

- Update time zone data files to tzdata release 2008i (for DST law changes in Argentina, Brazil, Mauritius, Syria)

E.117. Release 8.2.10

Release Date: 2008-09-22

This release contains a variety of fixes from 8.2.9. For information about new features in the 8.2 major release, see Section E.127.

E.117.1. Migration to Version 8.2.10

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.7, see Section E.120.

E.117.2. Changes

- Fix bug in btree WAL recovery code (Heikki)

  Recovery failed if the WAL ended partway through a page split operation.

- Fix potential miscalculation of `datfrozenxid` (Alvaro)

  This error may explain some recent reports of failure to remove old `pg_clog` data.

- Widen local lock counters from 32 to 64 bits (Tom)

  This responds to reports that the counters could overflow in sufficiently long transactions, leading to unexpected "lock is already held" errors.

- Fix possible duplicate output of tuples during a GiST index scan (Teodor)

- Fix missed permissions checks when a view contains a simple `UNION ALL` construct (Heikki)

  Permissions for the referenced tables were checked properly, but not permissions for the view itself.

- Add checks in executor startup to ensure that the tuples produced by an `INSERT` or `UPDATE` will match the target table's current rowtype (Tom)

  `ALTER COLUMN TYPE`, followed by re-use of a previously cached plan, could produce this type of situation. The check protects against data corruption and/or crashes that could ensue.

- Fix possible repeated drops during `DROP OWNED` (Tom)

  This would typically result in strange errors such as "cache lookup failed for relation NNN".

- Fix `AT TIME ZONE` to first try to interpret its timezone argument as a timezone abbreviation, and only try it as a full timezone name if that fails, rather than the other way around as formerly (Tom)

  The timestamp input functions have always resolved ambiguous zone names in this order. Making `AT TIME ZONE` do so as well improves consistency, and fixes a compatibility bug introduced in 8.1: in ambiguous cases we now behave the same as 8.0 and before did, since in the older versions `AT TIME ZONE` accepted *only* abbreviations.

- Fix datetime input functions to correctly detect integer overflow when running on a 64-bit platform (Tom)

- Prevent integer overflows during units conversion when displaying a configuration parameter that has units (Tom)

- Improve performance of writing very long log messages to syslog (Tom)

- Allow spaces in the suffix part of an LDAP URL in `pg_hba.conf` (Tom)

- Fix bug in backwards scanning of a cursor on a `SELECT DISTINCT ON` query (Tom)

- Fix planner bug with nested sub-select expressions (Tom)

  If the outer sub-select has no direct dependency on the parent query, but the inner one does, the outer value might not get recalculated for new parent query rows.

- Fix planner to estimate that `GROUP BY` expressions yielding boolean results always result in two groups, regardless of the expressions' contents (Tom)

This is very substantially more accurate than the regular `GROUP BY` estimate for certain boolean tests like *col* `IS NULL`.

- Fix PL/pgSQL to not fail when a `FOR` loop's target variable is a record containing composite-type fields (Tom)
- Fix PL/Tcl to behave correctly with Tcl 8.5, and to be more careful about the encoding of data sent to or from Tcl (Tom)
- On Windows, work around a Microsoft bug by preventing libpq from trying to send more than 64kB per system call (Magnus)
- Improve pg_dump and pg_restore's error reporting after failure to send a SQL command (Tom)
- Fix pg_ctl to properly preserve postmaster command-line arguments across a `restart` (Bruce)
- Update time zone data files to tzdata release 2008f (for DST law changes in Argentina, Bahamas, Brazil, Mauritius, Morocco, Pakistan, Palestine, and Paraguay)

E.118. Release 8.2.9

Release Date: 2008-06-12

This release contains one serious and one minor bug fix over 8.2.8. For information about new features in the 8.2 major release, see Section E.127.

E.118.1. Migration to Version 8.2.9

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.7, see Section E.120.

E.118.2. Changes

- Make `pg_get_ruledef()` parenthesize negative constants (Tom)

  Before this fix, a negative constant in a view or rule might be dumped as, say, `-42::integer`, which is subtly incorrect: it should be `(-42)::integer` due to operator precedence rules. Usually this would make little difference, but it could interact with another recent patch to cause PostgreSQL to reject what had been a valid `SELECT DISTINCT` view query. Since this could result in pg_dump output failing to reload, it is being treated as a high-priority fix. The only released versions in which dump output is actually incorrect are 8.3.1 and 8.2.7.

- Make `ALTER AGGREGATE ... OWNER TO` update `pg_shdepend` (Tom)

  This oversight could lead to problems if the aggregate was later involved in a `DROP OWNED` or `REASSIGN OWNED` operation.

E.119. Release 8.2.8

Release Date: never released

This release contains a variety of fixes from 8.2.7. For information about new features in the 8.2 major release, see Section E.127.

E.119.1. Migration to Version 8.2.8

A dump/restore is not required for those running 8.2.X. However, if you are upgrading from a version earlier than 8.2.7, see Section E.120.

E.119.2. Changes

- Fix `ERRORDATA_STACK_SIZE exceeded` crash that occurred on Windows when using UTF-8 database encoding and a different client encoding (Tom)
- Fix `ALTER TABLE ADD COLUMN ... PRIMARY KEY` so that the new column is correctly checked to see if it's been initialized to all non-nulls (Brendan Jurd)

  Previous versions neglected to check this requirement at all.
- Fix possible `CREATE TABLE` failure when inheriting the "same" constraint from multiple parent relations that inherited that constraint from a common ancestor (Tom)
- Fix `pg_get_ruledef()` to show the alias, if any, attached to the target table of an `UPDATE` or `DELETE` (Tom)
- Fix GIN bug that could result in a `too many LWLocks taken` failure (Teodor)
- Avoid possible crash when decompressing corrupted data (Zdenek Kotala)
- Repair two places where SIGTERM exit of a backend could leave corrupted state in shared memory (Tom)

  Neither case is very important if SIGTERM is used to shut down the whole database cluster together, but there was a problem if someone tried to SIGTERM individual backends.
- Fix conversions between ISO-8859-5 and other encodings to handle Cyrillic "Yo" characters (`ё` and `Ё` with two dots) (Sergey Burladyan)
- Fix several datatype input functions, notably `array_in()`, that were allowing unused bytes in their results to contain uninitialized, unpredictable values (Tom)

  This could lead to failures in which two apparently identical literal values were not seen as equal, resulting in the parser complaining about unmatched `ORDER BY` and `DISTINCT` expressions.
- Fix a corner case in regular-expression substring matching (`substring(`*`string`*` from `*`pattern`*`)`) (Tom)

  The problem occurs when there is a match to the pattern overall but the user has specified a parenthesized subexpression and that subexpression hasn't got a match. An example is `substring('foo' from 'foo(bar)?')`. This should return NULL, since `(bar)` isn't matched, but it was mistakenly returning the whole-pattern match instead (ie, `foo`).

- Update time zone data files to tzdata release 2008c (for DST law changes in Morocco, Iraq, Choibalsan, Pakistan, Syria, Cuba, and Argentina/San_Luis)
- Fix incorrect result from ecpg's `PGTYPEStimestamp_sub()` function (Michael)
- Fix broken GiST comparison function for `contrib/tsearch2`'s `tsquery` type (Teodor)
- Fix possible crashes in `contrib/cube` functions (Tom)
- Fix core dump in `contrib/xml2`'s `xpath_table()` function when the input query returns a NULL value (Tom)
- Fix `contrib/xml2`'s makefile to not override `CFLAGS` (Tom)
- Fix `DatumGetBool` macro to not fail with gcc 4.3 (Tom)

  This problem affects "old style" (V0) C functions that return boolean. The fix is already in 8.3, but the need to back-patch it was not realized at the time.

E.120. Release 8.2.7

Release Date: 2008-03-17

This release contains a variety of fixes from 8.2.6. For information about new features in the 8.2 major release, see Section E.127.

E.120.1. Migration to Version 8.2.7

A dump/restore is not required for those running 8.2.X. However, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the Windows locale issue described below.

E.120.2. Changes

- Fix character string comparison for Windows locales that consider different character combinations as equal (Tom)

  This fix applies only on Windows and only when using UTF-8 database encoding. The same fix was made for all other cases over two years ago, but Windows with UTF-8 uses a separate code path that was not updated. If you are using a locale that considers some non-identical strings as equal, you may need to `REINDEX` to fix existing indexes on textual columns.
- Repair potential deadlock between concurrent `VACUUM FULL` operations on different system catalogs (Tom)
- Fix longstanding `LISTEN`/`NOTIFY` race condition (Tom)

  In rare cases a session that had just executed a `LISTEN` might not get a notification, even though one would be expected because the concurrent transaction executing `NOTIFY` was observed to commit later.

  A side effect of the fix is that a transaction that has executed a not-yet-committed `LISTEN` command will not see any row in `pg_listener` for the `LISTEN`, should it choose to look; formerly it

would have. This behavior was never documented one way or the other, but it is possible that some applications depend on the old behavior.

- Disallow `LISTEN` and `UNLISTEN` within a prepared transaction (Tom)

  This was formerly allowed but trying to do it had various unpleasant consequences, notably that the originating backend could not exit as long as an `UNLISTEN` remained uncommitted.

- Disallow dropping a temporary table within a prepared transaction (Heikki)

  This was correctly disallowed by 8.1, but the check was inadvertently broken in 8.2.

- Fix rare crash when an error occurs during a query using a hash index (Heikki)

- Fix memory leaks in certain usages of set-returning functions (Neil)

- Fix input of datetime values for February 29 in years BC (Tom)

  The former coding was mistaken about which years were leap years.

- Fix "unrecognized node type" error in some variants of `ALTER OWNER` (Tom)

- Ensure `pg_stat_activity.waiting` flag is cleared when a lock wait is aborted (Tom)

- Fix handling of process permissions on Windows Vista (Dave, Magnus)

  In particular, this fix allows starting the server as the Administrator user.

- Update time zone data files to tzdata release 2008a (in particular, recent Chile changes); adjust timezone abbreviation `VET` (Venezuela) to mean UTC-4:30, not UTC-4:00 (Tom)

- Fix pg_ctl to correctly extract the postmaster's port number from command-line options (Itagaki Takahiro, Tom)

  Previously, `pg_ctl start -w` could try to contact the postmaster on the wrong port, leading to bogus reports of startup failure.

- Use `-fwrapv` to defend against possible misoptimization in recent gcc versions (Tom)

  This is known to be necessary when building PostgreSQL with gcc 4.3 or later.

- Correctly enforce `statement_timeout` values longer than `INT_MAX` microseconds (about 35 minutes) (Tom)

  This bug affects only builds with `--enable-integer-datetimes`.

- Fix "unexpected PARAM_SUBLINK ID" planner error when constant-folding simplifies a subselect (Tom)

- Fix logical errors in constraint-exclusion handling of `IS NULL` and `NOT` expressions (Tom)

  The planner would sometimes exclude partitions that should not have been excluded because of the possibility of NULL results.

- Fix another cause of "failed to build any N-way joins" planner errors (Tom)

  This could happen in cases where a clauseless join needed to be forced before a join clause could be exploited.

- Fix incorrect constant propagation in outer-join planning (Tom)

  The planner could sometimes incorrectly conclude that a variable could be constrained to be equal to a constant, leading to wrong query results.

- Fix display of constant expressions in `ORDER BY` and `GROUP BY` (Tom)

  An explicitly casted constant would be shown incorrectly. This could for example lead to corruption of a view definition during dump and reload.

- Fix libpq to handle NOTICE messages correctly during COPY OUT (Tom)

  This failure has only been observed to occur when a user-defined datatype's output routine issues a NOTICE, but there is no guarantee it couldn't happen due to other causes.

E.121. Release 8.2.6

Release Date: 2008-01-07

This release contains a variety of fixes from 8.2.5, including fixes for significant security issues. For information about new features in the 8.2 major release, see Section E.127.

E.121.1. Migration to Version 8.2.6

A dump/restore is not required for those running 8.2.X.

E.121.2. Changes

- Prevent functions in indexes from executing with the privileges of the user running `VACUUM`, `ANALYZE`, etc (Tom)

  Functions used in index expressions and partial-index predicates are evaluated whenever a new table entry is made. It has long been understood that this poses a risk of trojan-horse code execution if one modifies a table owned by an untrustworthy user. (Note that triggers, defaults, check constraints, etc. pose the same type of risk.) But functions in indexes pose extra danger because they will be executed by routine maintenance operations such as `VACUUM FULL`, which are commonly performed automatically under a superuser account. For example, a nefarious user can execute code with superuser privileges by setting up a trojan-horse index definition and waiting for the next routine vacuum. The fix arranges for standard maintenance operations (including `VACUUM`, `ANALYZE`, `REINDEX`, and `CLUSTER`) to execute as the table owner rather than the calling user, using the same privilege-switching mechanism already used for `SECURITY DEFINER` functions. To prevent bypassing this security measure, execution of `SET SESSION AUTHORIZATION` and `SET ROLE` is now forbidden within a `SECURITY DEFINER` context. (CVE-2007-6600)

- Repair assorted bugs in the regular-expression package (Tom, Will Drewry)

  Suitably crafted regular-expression patterns could cause crashes, infinite or near-infinite looping, and/or massive memory consumption, all of which pose denial-of-service hazards for applications that accept regex search patterns from untrustworthy sources. (CVE-2007-4769, CVE-2007-4772, CVE-2007-6067)

- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

  The fix that appeared for this in 8.2.5 was incomplete, as it plugged the hole for only some `dblink` functions. (CVE-2007-6601, CVE-2007-3278)

- Fix bugs in WAL replay for GIN indexes (Teodor)

- Fix GIN index build to work properly when `maintenance_work_mem` is 4GB or more (Tom)

- Update time zone data files to tzdata release 2007k (in particular, recent Argentina changes) (Tom)
- Improve planner's handling of LIKE/regex estimation in non-C locales (Tom)
- Fix planning-speed problem for deep outer-join nests, as well as possible poor choice of join order (Tom)
- Fix planner failure in some cases of `WHERE false AND var IN (SELECT ...)` (Tom)
- Make `CREATE TABLE ... SERIAL` and `ALTER SEQUENCE ... OWNED BY` not change the `currval()` state of the sequence (Tom)
- Preserve the tablespace and storage parameters of indexes that are rebuilt by `ALTER TABLE ... ALTER COLUMN TYPE` (Tom)
- Make archive recovery always start a new WAL timeline, rather than only when a recovery stop time was used (Simon)

  This avoids a corner-case risk of trying to overwrite an existing archived copy of the last WAL segment, and seems simpler and cleaner than the original definition.
- Make `VACUUM` not use all of `maintenance_work_mem` when the table is too small for it to be useful (Alvaro)
- Fix potential crash in `translate()` when using a multibyte database encoding (Tom)
- Make `corr()` return the correct result for negative correlation values (Neil)
- Fix overflow in `extract(epoch from interval)` for intervals exceeding 68 years (Tom)
- Fix PL/Perl to not fail when a UTF-8 regular expression is used in a trusted function (Andrew)
- Fix PL/Perl to cope when platform's Perl defines type `bool` as `int` rather than `char` (Tom)

  While this could theoretically happen anywhere, no standard build of Perl did things this way ... until Mac OS X 10.5.
- Fix PL/Python to work correctly with Python 2.5 on 64-bit machines (Marko Kreen)
- Fix PL/Python to not crash on long exception messages (Alvaro)
- Fix pg_dump to correctly handle inheritance child tables that have default expressions different from their parent's (Tom)
- Fix libpq crash when `PGPASSFILE` refers to a file that is not a plain file (Martin Pitt)
- ecpg parser fixes (Michael)
- Make `contrib/pgcrypto` defend against OpenSSL libraries that fail on keys longer than 128 bits; which is the case at least on some Solaris versions (Marko Kreen)
- Make `contrib/tablefunc`'s `crosstab()` handle NULL rowid as a category in its own right, rather than crashing (Joe)
- Fix `tsvector` and `tsquery` output routines to escape backslashes correctly (Teodor, Bruce)
- Fix crash of `to_tsvector()` on huge input strings (Teodor)
- Require a specific version of Autoconf to be used when re-generating the `configure` script (Peter)

  This affects developers and packagers only. The change was made to prevent accidental use of untested combinations of Autoconf and PostgreSQL versions. You can remove the version check if you really want to use a different Autoconf version, but it's your responsibility whether the result works or not.
- Update `gettimeofday` configuration check so that PostgreSQL can be built on newer versions of MinGW (Magnus)

E.122. Release 8.2.5

Release Date: 2007-09-17

This release contains a variety of fixes from 8.2.4. For information about new features in the 8.2 major release, see Section E.127.

E.122.1. Migration to Version 8.2.5

A dump/restore is not required for those running 8.2.X.

E.122.2. Changes

- Prevent index corruption when a transaction inserts rows and then aborts close to the end of a concurrent `VACUUM` on the same table (Tom)
- Fix `ALTER DOMAIN ADD CONSTRAINT` for cases involving domains over domains (Tom)
- Make `CREATE DOMAIN ... DEFAULT NULL` work properly (Tom)
- Fix some planner problems with outer joins, notably poor size estimation for `t1 LEFT JOIN t2 WHERE t2.col IS NULL` (Tom)
- Allow the `interval` data type to accept input consisting only of milliseconds or microseconds (Neil)
- Allow timezone name to appear before the year in `timestamp` input (Tom)
- Fixes for GIN indexes used by `/contrib/tsearch2` (Teodor)
- Speed up rtree index insertion (Teodor)
- Fix excessive logging of SSL error messages (Tom)
- Fix logging so that log messages are never interleaved when using the syslogger process (Andrew)
- Fix crash when `log_min_error_statement` logging runs out of memory (Tom)
- Fix incorrect handling of some foreign-key corner cases (Tom)
- Fix `stddev_pop(numeric)` and `var_pop(numeric)` (Tom)
- Prevent `REINDEX` and `CLUSTER` from failing due to attempting to process temporary tables of other sessions (Alvaro)
- Update the time zone database rules, particularly New Zealand's upcoming changes (Tom)
- Windows socket and semaphore improvements (Magnus)
- Make `pg_ctl -w` work properly in Windows service mode (Dave Page)
- Fix memory allocation bug when using MIT Kerberos on Windows (Magnus)
- Suppress timezone name (`%Z`) in log timestamps on Windows because of possible encoding mismatches (Tom)
- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)
- Restrict `/contrib/pgstattuple` functions to superusers, for security reasons (Tom)

- Do not let `/contrib/intarray` try to make its GIN opclass the default (this caused problems at dump/restore) (Tom)

E.123. Release 8.2.4

Release Date: 2007-04-23

This release contains a variety of fixes from 8.2.3, including a security fix. For information about new features in the 8.2 major release, see Section E.127.

E.123.1. Migration to Version 8.2.4

A dump/restore is not required for those running 8.2.X.

E.123.2. Changes

- Support explicit placement of the temporary-table schema within `search_path`, and disable searching it for functions and operators (Tom)

  This is needed to allow a security-definer function to set a truly secure value of `search_path`. Without it, an unprivileged SQL user can use temporary objects to execute code with the privileges of the security-definer function (CVE-2007-2138). See `CREATE FUNCTION` for more information.
- Fix `shared_preload_libraries` for Windows by forcing reload in each backend (Korry Douglas)
- Fix `to_char()` so it properly upper/lower cases localized day or month names (Pavel Stehule)
- `/contrib/tsearch2` crash fixes (Teodor)
- Require `COMMIT PREPARED` to be executed in the same database as the transaction was prepared in (Heikki)
- Allow `pg_dump` to do binary backups larger than two gigabytes on Windows (Magnus)
- New traditional (Taiwan) Chinese FAQ (Zhou Daojing)
- Prevent the statistics collector from writing to disk too frequently (Tom)
- Fix potential-data-corruption bug in how `VACUUM FULL` handles `UPDATE` chains (Tom, Pavan Deolasee)
- Fix bug in domains that use array types (Tom)
- Fix `pg_dump` so it can dump a serial column's sequence using `-t` when not also dumping the owning table (Tom)
- Planner fixes, including improving outer join and bitmap scan selection logic (Tom)
- Fix possible wrong answers or crash when a PL/pgSQL function tries to `RETURN` from within an `EXCEPTION` block (Tom)
- Fix PANIC during enlargement of a hash index (Tom)

- Fix POSIX-style timezone specs to follow new USA DST rules (Tom)

E.124. Release 8.2.3

Release Date: 2007-02-07

This release contains two fixes from 8.2.2. For information about new features in the 8.2 major release, see Section E.127.

E.124.1. Migration to Version 8.2.3

A dump/restore is not required for those running 8.2.X.

E.124.2. Changes

- Remove overly-restrictive check for type length in constraints and functional indexes(Tom)
- Fix optimization so MIN/MAX in subqueries can again use indexes (Tom)

E.125. Release 8.2.2

Release Date: 2007-02-05

This release contains a variety of fixes from 8.2.1, including a security fix. For information about new features in the 8.2 major release, see Section E.127.

E.125.1. Migration to Version 8.2.2

A dump/restore is not required for those running 8.2.X.

E.125.2. Changes

- Remove security vulnerabilities that allowed connected users to read backend memory (Tom)

  The vulnerabilities involve suppressing the normal check that a SQL function returns the data type it's declared to, and changing the data type of a table column (CVE-2007-0555, CVE-2007-0556). These errors can easily be exploited to cause a backend crash, and in principle might be used to read database content that the user should not be able to access.

- Fix not-so-rare-anymore bug wherein btree index page splits could fail due to choosing an infeasible split point (Heikki Linnakangas)
- Fix Borland C compile scripts (L Bayuk)
- Properly handle `to_char('CC')` for years ending in `00` (Tom)

  Year 2000 is in the twentieth century, not the twenty-first.
- `/contrib/tsearch2` localization improvements (Tatsuo, Teodor)
- Fix incorrect permission check in `information_schema.key_column_usage` view (Tom)

  The symptom is "relation with OID nnnnn does not exist" errors. To get this fix without using `initdb`, use `CREATE OR REPLACE VIEW` to install the corrected definition found in `share/information_schema.sql`. Note you will need to do this in each database.
- Improve `VACUUM` performance for databases with many tables (Tom)
- Fix for rare Assert() crash triggered by `UNION` (Tom)
- Fix potentially incorrect results from index searches using `ROW` inequality conditions (Tom)
- Tighten security of multi-byte character processing for UTF8 sequences over three bytes long (Tom)
- Fix bogus "permission denied" failures occurring on Windows due to attempts to fsync already-deleted files (Magnus, Tom)
- Fix bug that could cause the statistics collector to hang on Windows (Magnus)

  This would in turn lead to autovacuum not working.
- Fix possible crashes when an already-in-use PL/pgSQL function is updated (Tom)
- Improve PL/pgSQL handling of domain types (Sergiy Vyshnevetskiy, Tom)
- Fix possible errors in processing PL/pgSQL exception blocks (Tom)

E.126. Release 8.2.1

Release Date: 2007-01-08

This release contains a variety of fixes from 8.2. For information about new features in the 8.2 major release, see Section E.127.

E.126.1. Migration to Version 8.2.1

A dump/restore is not required for those running 8.2.

E.126.2. Changes

- Fix crash with `SELECT ... LIMIT ALL` (also `LIMIT NULL`) (Tom)
- `Several /contrib/tsearch2` fixes (Teodor)

- On Windows, make log messages coming from the operating system use ASCII encoding (Hiroshi Saito)

  This fixes a conversion problem when there is a mismatch between the encoding of the operating system and database server.
- Fix Windows linking of pg_dump using `win32.mak` (Hiroshi Saito)
- Fix planner mistakes for outer join queries (Tom)
- Fix several problems in queries involving sub-SELECTs (Tom)
- Fix potential crash in SPI during subtransaction abort (Tom)

  This affects all PL functions since they all use SPI.
- Improve build speed of PDF documentation (Peter)
- Re-add JST (Japan) timezone abbreviation (Tom)
- Improve optimization decisions related to index scans (Tom)
- Have psql print multi-byte combining characters as before, rather than output as `\u` (Tom)
- Improve index usage of regular expressions that use parentheses (Tom)

  This improves psql `\d` performance also.
- Make pg_dumpall assume that databases have public `CONNECT` privilege, when dumping from a pre-8.2 server (Tom)

  This preserves the previous behavior that anyone can connect to a database if allowed by `pg_hba.conf`.

E.127. Release 8.2

Release Date: 2006-12-05

E.127.1. Overview

This release adds many functionality and performance improvements that were requested by users, including:

- Query language enhancements including `INSERT/UPDATE/DELETE RETURNING`, multirow `VALUES` lists, and optional target-table alias in `UPDATE`/`DELETE`
- Index creation without blocking concurrent `INSERT`/`UPDATE`/`DELETE` operations
- Many query optimization improvements, including support for reordering outer joins
- Improved sorting performance with lower memory usage
- More efficient locking with better concurrency
- More efficient vacuuming
- Easier administration of warm standby servers
- New `FILLFACTOR` support for tables and indexes

- Monitoring, logging, and performance tuning additions
- More control over creating and dropping objects
- Table inheritance relationships can be defined for and removed from pre-existing tables
- `COPY TO` can copy the output of an arbitrary `SELECT` statement
- Array improvements, including nulls in arrays
- Aggregate-function improvements, including multiple-input aggregates and SQL:2003 statistical functions
- Many `contrib/` improvements

E.127.2. Migration to Version 8.2

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

- Set `escape_string_warning` to `on` by default (Bruce)

  This issues a warning if backslash escapes are used in non-escape (non-`E''`) strings.

- Change the row constructor syntax (`ROW(...)`) so that list elements `foo.*` will be expanded to a list of their member fields, rather than creating a nested row type field as formerly (Tom)

  The new behavior is substantially more useful since it allows, for example, triggers to check for data changes with `IF row(new.*) IS DISTINCT FROM row(old.*)`. The old behavior is still available by omitting `.*`.

- Make row comparisons follow SQL standard semantics and allow them to be used in index scans (Tom)

  Previously, row = and <> comparisons followed the standard but < <= > >= did not. A row comparison can now be used as an index constraint for a multicolumn index matching the row value.

- Make row `IS [NOT] NULL` tests follow SQL standard semantics (Tom)

  The former behavior conformed to the standard for simple cases with `IS NULL`, but `IS NOT NULL` would return true if any row field was non-null, whereas the standard says it should return true only when all fields are non-null.

- Make `SET CONSTRAINT` affect only one constraint (Kris Jurka)

  In previous releases, `SET CONSTRAINT` modified all constraints with a matching name. In this release, the schema search path is used to modify only the first matching constraint. A schema specification is also supported. This more nearly conforms to the SQL standard.

- Remove `RULE` permission for tables, for security reasons (Tom)

  As of this release, only a table's owner can create or modify rules for the table. For backwards compatibility, `GRANT`/`REVOKE RULE` is still accepted, but it does nothing.

- Array comparison improvements (Tom)

  Now array dimensions are also compared.

- Change array concatenation to match documented behavior (Tom)

This changes the previous behavior where concatenation would modify the array lower bound.

- Make command-line options of postmaster and postgres identical (Peter)

  This allows the postmaster to pass arguments to each backend without using `-o`. Note that some options are now only available as long-form options, because there were conflicting single-letter options.

- Deprecate use of postmaster symbolic link (Peter)

  postmaster and postgres commands now act identically, with the behavior determined by command-line options. The postmaster symbolic link is kept for compatibility, but is not really needed.

- Change `log_duration` to output even if the query is not output (Tom)

  In prior releases, `log_duration` only printed if the query appeared earlier in the log.

- Make `to_char(time)` and `to_char(interval)` treat `HH` and `HH12` as 12-hour intervals

  Most applications should use `HH24` unless they want a 12-hour display.

- Zero unmasked bits in conversion from `INET` to `CIDR` (Tom)

  This ensures that the converted value is actually valid for `CIDR`.

- Remove `australian_timezones` configuration variable (Joachim Wieland)

  This variable has been superseded by a more general facility for configuring timezone abbreviations.

- Improve cost estimation for nested-loop index scans (Tom)

  This might eliminate the need to set unrealistically small values of `random_page_cost`. If you have been using a very small `random_page_cost`, please recheck your test cases.

- Change behavior of `pg_dump -n` and `-t` options. (Greg Sabino Mullane)

  See the `pg_dump` manual page for details.

- Change libpq `PQdsplen()` to return a useful value (Martijn van Oosterhout)

- Declare libpq `PQgetssl()` as returning `void *`, rather than `SSL *` (Martijn van Oosterhout)

  This allows applications to use the function without including the OpenSSL headers.

- C-language loadable modules must now include a `PG_MODULE_MAGIC` macro call for version compatibility checking (Martijn van Oosterhout)

- For security's sake, modules used by a PL/PerlU function are no longer available to PL/Perl functions (Andrew)

  > **Note:** This also implies that data can no longer be shared between a PL/Perl function and a PL/PerlU function. Some Perl installations have not been compiled with the correct flags to allow multiple interpreters to exist within a single process. In this situation PL/Perl and PL/PerlU cannot both be used in a single backend. The solution is to get a Perl installation which supports multiple interpreters.

- In `contrib/xml2/`, rename `xml_valid()` to `xml_is_well_formed()` (Tom)

  `xml_valid()` will remain for backward compatibility, but its behavior will change to do schema checking in a future release.

- Remove `contrib/ora2pg/`, now at http://www.samse.fr/GPL/ora2pg

- Remove contrib modules that have been migrated to PgFoundry: `adddepend`, `dbase`, `dbmirror`, `fulltextindex`, `mac`, `userlock`
- Remove abandoned contrib modules: `mSQL-interface`, `tips`
- Remove QNX and BEOS ports (Bruce)

  These ports no longer had active maintainers.

E.127.3. Changes

Below you will find a detailed account of the changes between PostgreSQL 8.2 and the previous major release.

E.127.3.1. Performance Improvements

- Allow the planner to reorder outer joins in some circumstances (Tom)

  In previous releases, outer joins would always be evaluated in the order written in the query. This change allows the query optimizer to consider reordering outer joins, in cases where it can determine that the join order can be changed without altering the meaning of the query. This can make a considerable performance difference for queries involving multiple outer joins or mixed inner and outer joins.
- Improve efficiency of `IN` (list-of-expressions) clauses (Tom)
- Improve sorting speed and reduce memory usage (Simon, Tom)
- Improve subtransaction performance (Alvaro, Itagaki Takahiro, Tom)
- Add `FILLFACTOR` to table and index creation (ITAGAKI Takahiro)

  This leaves extra free space in each table or index page, allowing improved performance as the database grows. This is particularly valuable to maintain clustering.
- Increase default values for `shared_buffers` and `max_fsm_pages` (Andrew)
- Improve locking performance by breaking the lock manager tables into sections (Tom)

  This allows locking to be more fine-grained, reducing contention.
- Reduce locking requirements of sequential scans (Qingqing Zhou)
- Reduce locking required for database creation and destruction (Tom)
- Improve the optimizer's selectivity estimates for `LIKE`, `ILIKE`, and regular expression operations (Tom)
- Improve planning of joins to inherited tables and `UNION ALL` views (Tom)
- Allow constraint exclusion to be applied to inherited `UPDATE` and `DELETE` queries (Tom)

  `SELECT` already honored constraint exclusion.
- Improve planning of constant `WHERE` clauses, such as a condition that depends only on variables inherited from an outer query level (Tom)
- Protocol-level unnamed prepared statements are re-planned for each set of `BIND` values (Tom)

  This improves performance because the exact parameter values can be used in the plan.
- Speed up vacuuming of B-Tree indexes (Heikki Linnakangas, Tom)
- Avoid extra scan of tables without indexes during `VACUUM` (Greg Stark)

- Improve multicolumn GiST indexing (Oleg, Teodor)
- Remove dead index entries before B-Tree page split (Junji Teramoto)

E.127.3.2. Server Changes

- Allow a forced switch to a new transaction log file (Simon, Tom)

  This is valuable for keeping warm standby slave servers in sync with the master. Transaction log file switching now also happens automatically during `pg_stop_backup()`. This ensures that all transaction log files needed for recovery can be archived immediately.

- Add WAL informational functions (Simon)

  Add functions for interrogating the current transaction log insertion point and determining WAL filenames from the hex WAL locations displayed by `pg_stop_backup()` and related functions.

- Improve recovery from a crash during WAL replay (Simon)

  The server now does periodic checkpoints during WAL recovery, so if there is a crash, future WAL recovery is shortened. This also eliminates the need for warm standby servers to replay the entire log since the base backup if they crash.

- Improve reliability of long-term WAL replay (Heikki, Simon, Tom)

  Formerly, trying to roll forward through more than 2 billion transactions would not work due to XID wraparound. This meant warm standby servers had to be reloaded from fresh base backups periodically.

- Add `archive_timeout` to force transaction log file switches at a given interval (Simon)

  This enforces a maximum replication delay for warm standby servers.

- Add native LDAP authentication (Magnus Hagander)

  This is particularly useful for platforms that do not support PAM, such as Windows.

- Add `GRANT CONNECT ON DATABASE` (Gevik Babakhani)

  This gives SQL-level control over database access. It works as an additional filter on top of the existing `pg_hba.conf` controls.

- Add support for SSL Certificate Revocation List (CRL) files (Libor Hohoš)

  The server and libpq both recognize CRL files now.

- GiST indexes are now clusterable (Teodor)
- Remove routine autovacuum server log entries (Bruce)

  `pg_stat_activity` now shows autovacuum activity.

- Track maximum XID age within individual tables, instead of whole databases (Alvaro)

  This reduces the overhead involved in preventing transaction ID wraparound, by avoiding unnecessary VACUUMs.

- Add last vacuum and analyze timestamp columns to the stats collector (Larry Rosenman)

  These values now appear in the `pg_stat_*_tables` system views.

- Improve performance of statistics monitoring, especially `stats_command_string` (Tom, Bruce)

  This release enables `stats_command_string` by default, now that its overhead is minimal. This means `pg_stat_activity` will now show all active queries by default.

- Add a `waiting` column to `pg_stat_activity` (Tom)

  This allows `pg_stat_activity` to show all the information included in the ps display.

- Add configuration parameter `update_process_title` to control whether the ps display is updated for every command (Bruce)

  On platforms where it is expensive to update the ps display, it might be worthwhile to turn this off and rely solely on `pg_stat_activity` for status information.

- Allow units to be specified in configuration settings (Peter)

  For example, you can now set `shared_buffers` to `32MB` rather than mentally converting sizes.

- Add support for include directives in `postgresql.conf` (Joachim Wieland)

- Improve logging of protocol-level prepare/bind/execute messages (Bruce, Tom)

  Such logging now shows statement names, bind parameter values, and the text of the query being executed. Also, the query text is properly included in logged error messages when enabled by `log_min_error_statement`.

- Prevent `max_stack_depth` from being set to unsafe values

  On platforms where we can determine the actual kernel stack depth limit (which is most), make sure that the initial default value of `max_stack_depth` is safe, and reject attempts to set it to unsafely large values.

- Enable highlighting of error location in query in more cases (Tom)

  The server is now able to report a specific error location for some semantic errors (such as unrecognized column name), rather than just for basic syntax errors as before.

- Fix "failed to re-find parent key" errors in `VACUUM` (Tom)

- Clean out `pg_internal.init` cache files during server restart (Simon)

  This avoids a hazard that the cache files might contain stale data after PITR recovery.

- Fix race condition for truncation of a large relation across a gigabyte boundary by `VACUUM` (Tom)

- Fix bug causing needless deadlock errors on row-level locks (Tom)

- Fix bugs affecting multi-gigabyte hash indexes (Tom)

- Each backend process is now its own process group leader (Tom)

  This allows query cancel to abort subprocesses invoked from a backend or archive/recovery process.

E.127.3.3. Query Changes

- Add `INSERT`/`UPDATE`/`DELETE` `RETURNING` (Jonah Harris, Tom)

  This allows these commands to return values, such as the computed serial key for a new row. In the `UPDATE` case, values from the updated version of the row are returned.

- Add support for multiple-row `VALUES` clauses, per SQL standard (Joe, Tom)

  This allows `INSERT` to insert multiple rows of constants, or queries to generate result sets using constants. For example, `INSERT ... VALUES (...), (...), ....`, and `SELECT * FROM (VALUES (...), (...), ....) AS alias(f1, ...)`.

- Allow `UPDATE` and `DELETE` to use an alias for the target table (Atsushi Ogawa)

The SQL standard does not permit an alias in these commands, but many database systems allow one anyway for notational convenience.

- Allow `UPDATE` to set multiple columns with a list of values (Susanne Ebrecht)

  This is basically a short-hand for assigning the columns and values in pairs. The syntax is `UPDATE tab SET (column, ...) = (val, ...)`.

- Make row comparisons work per standard (Tom)

  The forms <, <=, >, >= now compare rows lexicographically, that is, compare the first elements, if equal compare the second elements, and so on. Formerly they expanded to an AND condition across all the elements, which was neither standard nor very useful.

- Add `CASCADE` option to `TRUNCATE` (Joachim Wieland)

  This causes `TRUNCATE` to automatically include all tables that reference the specified table(s) via foreign keys. While convenient, this is a dangerous tool — use with caution!

- Support `FOR UPDATE` and `FOR SHARE` in the same `SELECT` command (Tom)

- Add `IS NOT DISTINCT FROM` (Pavel Stehule)

  This operator is similar to equality (=), but evaluates to true when both left and right operands are `NULL`, and to false when just one is, rather than yielding `NULL` in these cases.

- Improve the length output used by `UNION`/`INTERSECT`/`EXCEPT` (Tom)

  When all corresponding columns are of the same defined length, that length is used for the result, rather than a generic length.

- Allow `ILIKE` to work for multi-byte encodings (Tom)

  Internally, `ILIKE` now calls `lower()` and then uses `LIKE`. Locale-specific regular expression patterns still do not work in these encodings.

- Enable `standard_conforming_strings` to be turned `on` (Kevin Grittner)

  This allows backslash escaping in strings to be disabled, making PostgreSQL more standards-compliant. The default is `off` for backwards compatibility, but future releases will default this to `on`.

- Do not flatten subqueries that contain `volatile` functions in their target lists (Jaime Casanova)

  This prevents surprising behavior due to multiple evaluation of a `volatile` function (such as `random()` or `nextval()`). It might cause performance degradation in the presence of functions that are unnecessarily marked as `volatile`.

- Add system views `pg_prepared_statements` and `pg_cursors` to show prepared statements and open cursors (Joachim Wieland, Neil)

  These are very useful in pooled connection setups.

- Support portal parameters in `EXPLAIN` and `EXECUTE` (Tom)

  This allows, for example, JDBC `?` parameters to work in these commands.

- If SQL-level `PREPARE` parameters are unspecified, infer their types from the content of the query (Neil)

  Protocol-level `PREPARE` already did this.

- Allow `LIMIT` and `OFFSET` to exceed two billion (Dhanaraj M)

E.127.3.4. Object Manipulation Changes

- Add `TABLESPACE` clause to `CREATE TABLE AS` (Neil)

  This allows a tablespace to be specified for the new table.

- Add `ON COMMIT` clause to `CREATE TABLE AS` (Neil)

  This allows temporary tables to be truncated or dropped on transaction commit. The default behavior is for the table to remain until the session ends.

- Add `INCLUDING CONSTRAINTS` to `CREATE TABLE LIKE` (Greg Stark)

  This allows easy copying of `CHECK` constraints to a new table.

- Allow the creation of placeholder (shell) types (Martijn van Oosterhout)

  A shell type declaration creates a type name, without specifying any of the details of the type. Making a shell type is useful because it allows cleaner declaration of the type's input/output functions, which must exist before the type can be defined "for real". The syntax is `CREATE TYPE` *`typename`*.

- Aggregate functions now support multiple input parameters (Sergey Koposov, Tom)

- Add new aggregate creation syntax (Tom)

  The new syntax is `CREATE AGGREGATE` *`aggname`* `(`*`input_type`*`) (`*`parameter_list`*`)`. This more naturally supports the new multi-parameter aggregate functionality. The previous syntax is still supported.

- Add `ALTER ROLE PASSWORD NULL` to remove a previously set role password (Peter)

- Add `DROP` object `IF EXISTS` for many object types (Andrew)

  This allows `DROP` operations on non-existent objects without generating an error.

- Add `DROP OWNED` to drop all objects owned by a role (Alvaro)

- Add `REASSIGN OWNED` to reassign ownership of all objects owned by a role (Alvaro)

  This, and `DROP OWNED` above, facilitate dropping roles.

- Add `GRANT ON SEQUENCE` syntax (Bruce)

  This was added for setting sequence-specific permissions. `GRANT ON TABLE` for sequences is still supported for backward compatibility.

- Add `USAGE` permission for sequences that allows only `currval()` and `nextval()`, not `setval()` (Bruce)

  `USAGE` permission allows more fine-grained control over sequence access. Granting `USAGE` allows users to increment a sequence, but prevents them from setting the sequence to an arbitrary value using `setval()`.

- Add `ALTER TABLE [ NO ] INHERIT` (Greg Stark)

  This allows inheritance to be adjusted dynamically, rather than just at table creation and destruction. This is very valuable when using inheritance to implement table partitioning.

- Allow comments on global objects to be stored globally (Kris Jurka)

  Previously, comments attached to databases were stored in individual databases, making them ineffective, and there was no provision at all for comments on roles or tablespaces. This change adds a new shared catalog `pg_shdescription` and stores comments on databases, roles, and tablespaces therein.

E.127.3.5. Utility Command Changes

- Add option to allow indexes to be created without blocking concurrent writes to the table (Greg Stark, Tom)

  The new syntax is `CREATE INDEX CONCURRENTLY`. The default behavior is still to block table modification while an index is being created.

- Provide advisory locking functionality (Abhijit Menon-Sen, Tom)

  This is a new locking API designed to replace what used to be in /contrib/userlock. The userlock code is now on pgfoundry.

- Allow `COPY` to dump a `SELECT` query (Zoltan Boszormenyi, Karel Zak)

  This allows `COPY` to dump arbitrary SQL queries. The syntax is `COPY (SELECT ...) TO`.

- Make the `COPY` command return a command tag that includes the number of rows copied (Volkan YAZICI)

- Allow `VACUUM` to expire rows without being affected by other concurrent `VACUUM` operations (Hannu Krossing, Alvaro, Tom)

- Make initdb detect the operating system locale and set the default `DateStyle` accordingly (Peter)

  This makes it more likely that the installed `postgresql.conf DateStyle` value will be as desired.

- Reduce number of progress messages displayed by initdb (Tom)

E.127.3.6. Date/Time Changes

- Allow full timezone names in `timestamp` input values (Joachim Wieland)

  For example, `'2006-05-24 21:11 America/New_York'::timestamptz`.

- Support configurable timezone abbreviations (Joachim Wieland)

  A desired set of timezone abbreviations can be chosen via the configuration parameter `timezone_abbreviations`.

- Add `pg_timezone_abbrevs` and `pg_timezone_names` views to show supported timezones (Magnus Hagander)

- Add `clock_timestamp()`, `statement_timestamp()`, and `transaction_timestamp()` (Bruce)

  `clock_timestamp()` is the current wall-clock time, `statement_timestamp()` is the time the current statement arrived at the server, and `transaction_timestamp()` is an alias for `now()`.

- Allow `to_char()` to print localized month and day names (Euler Taveira de Oliveira)

- Allow `to_char(time)` and `to_char(interval)` to output AM/PM specifications (Bruce)

  Intervals and times are treated as 24-hour periods, e.g. `25 hours` is considered AM.

- Add new function `justify_interval()` to adjust interval units (Mark Dilger)

- Allow timezone offsets up to 14:59 away from GMT

  Kiribati uses GMT+14, so we'd better accept that.

- Interval computation improvements (Michael Glaesemann, Bruce)

E.127.3.7. Other Data Type and Function Changes

- Allow arrays to contain `NULL` elements (Tom)
- Allow assignment to array elements not contiguous with the existing entries (Tom)

  The intervening array positions will be filled with nulls. This is per SQL standard.
- New built-in operators for array-subset comparisons (`@>`, `<@`, `&&`) (Teodor, Tom)

  These operators can be indexed for many data types using GiST or GIN indexes.
- Add convenient arithmetic operations on `INET`/`CIDR` values (Stephen R. van den Berg)

  The new operators are `&` (and), `|` (or), `~` (not), `inet + int8`, `inet - int8`, and `inet - inet`.
- Add new aggregate functions from SQL:2003 (Neil)

  The new functions are `var_pop()`, `var_samp()`, `stddev_pop()`, and `stddev_samp()`. `var_samp()` and `stddev_samp()` are merely renamings of the existing aggregates `variance()` and `stddev()`. The latter names remain available for backward compatibility.
- Add SQL:2003 statistical aggregates (Sergey Koposov)

  New functions: `regr_intercept()`, `regr_slope()`, `regr_r2()`, `corr()`, `covar_samp()`, `covar_pop()`, `regr_avgx()`, `regr_avgy()`, `regr_sxy()`, `regr_sxx()`, `regr_syy()`, `regr_count()`.
- Allow domains to be based on other domains (Tom)
- Properly enforce domain `CHECK` constraints everywhere (Neil, Tom)

  For example, the result of a user-defined function that is declared to return a domain type is now checked against the domain's constraints. This closes a significant hole in the domain implementation.
- Fix problems with dumping renamed `SERIAL` columns (Tom)

  The fix is to dump a `SERIAL` column by explicitly specifying its `DEFAULT` and sequence elements, and reconstructing the `SERIAL` column on reload using a new `ALTER SEQUENCE OWNED BY` command. This also allows dropping a `SERIAL` column specification.
- Add a server-side sleep function `pg_sleep()` (Joachim Wieland)
- Add all comparison operators for the `tid` (tuple id) data type (Mark Kirkwood, Greg Stark, Tom)

E.127.3.8. PL/pgSQL Server-Side Language Changes

- Add `TG_table_name` and `TG_table_schema` to trigger parameters (Andrew)

  `TG_relname` is now deprecated. Comparable changes have been made in the trigger parameters for the other PLs as well.
- Allow `FOR` statements to return values to scalars as well as records and row types (Pavel Stehule)
- Add a `BY` clause to the `FOR` loop, to control the iteration increment (Jaime Casanova)
- Add `STRICT` to `SELECT INTO` (Matt Miller)

  `STRICT` mode throws an exception if more or less than one row is returned by the `SELECT`, for Oracle PL/SQL compatibility.

E.127.3.9. PL/Perl Server-Side Language Changes

- Add `table_name` and `table_schema` to trigger parameters (Adam Sjøgren)
- Add prepared queries (Dmitry Karasik)
- Make `$_TD` trigger data a global variable (Andrew)

  Previously, it was lexical, which caused unexpected sharing violations.
- Run PL/Perl and PL/PerlU in separate interpreters, for security reasons (Andrew)

  In consequence, they can no longer share data nor loaded modules. Also, if Perl has not been compiled with the requisite flags to allow multiple interpreters, only one of these languages can be used in any given backend process.

E.127.3.10. PL/Python Server-Side Language Changes

- Named parameters are passed as ordinary variables, as well as in the `args[]` array (Sven Suursoho)
- Add `table_name` and `table_schema` to trigger parameters (Andrew)
- Allow returning of composite types and result sets (Sven Suursoho)
- Return result-set as `list`, `iterator`, or `generator` (Sven Suursoho)
- Allow functions to return `void` (Neil)
- Python 2.5 is now supported (Tom)

E.127.3.11. psql Changes

- Add new command `\password` for changing role password with client-side password encryption (Peter)
- Allow `\c` to connect to a new host and port number (David, Volkan YAZICI)
- Add tablespace display to `\l+` (Philip Yarra)
- Improve `\df` slash command to include the argument names and modes (`OUT` or `INOUT`) of the function (David Fetter)
- Support binary `COPY` (Andreas Pflug)
- Add option to run the entire session in a single transaction (Simon)

  Use option `-1` or `--single-transaction`.
- Support for automatically retrieving `SELECT` results in batches using a cursor (Chris Mair)

  This is enabled using `\set FETCH_COUNT` *n*. This feature allows large result sets to be retrieved in psql without attempting to buffer the entire result set in memory.
- Make multi-line values align in the proper column (Martijn van Oosterhout)

  Field values containing newlines are now displayed in a more readable fashion.
- Save multi-line statements as a single entry, rather than one line at a time (Sergey E. Koposov)

  This makes up-arrow recall of queries easier. (This is not available on Windows, because that platform uses the native command-line editing present in the operating system.)

- Make the line counter 64-bit so it can handle files with more than two billion lines (David Fetter)
- Report both the returned data and the command status tag for `INSERT`/`UPDATE`/`DELETE RETURNING` (Tom)

E.127.3.12. pg_dump Changes

- Allow complex selection of objects to be included or excluded by pg_dump (Greg Sabino Mullane)

  pg_dump now supports multiple `-n` (schema) and `-t` (table) options, and adds `-N` and `-T` options to exclude objects. Also, the arguments of these switches can now be wild-card expressions rather than single object names, for example `-t 'foo*'`, and a schema can be part of a `-t` or `-T` switch, for example `-t schema1.table1`.
- Add pg_restore `--no-data-for-failed-tables` option to suppress loading data if table creation failed (i.e., the table already exists) (Martin Pitt)
- Add pg_restore option to run the entire session in a single transaction (Simon)

  Use option `-1` or `--single-transaction`.

E.127.3.13. libpq Changes

- Add `PQencryptPassword()` to encrypt passwords (Tom)

  This allows passwords to be sent pre-encrypted for commands like `ALTER ROLE ... PASSWORD`.
- Add function `PQisthreadsafe()` (Bruce)

  This allows applications to query the thread-safety status of the library.
- Add `PQdescribePrepared()`, `PQdescribePortal()`, and related functions to return information about previously prepared statements and open cursors (Volkan YAZICI)
- Allow LDAP lookups from `pg_service.conf` (Laurenz Albe)
- Allow a hostname in `~/.pgpass` to match the default socket directory (Bruce)

  A blank hostname continues to match any Unix-socket connection, but this addition allows entries that are specific to one of several postmasters on the machine.

E.127.3.14. ecpg Changes

- Allow `SHOW` to put its result into a variable (Joachim Wieland)
- Add `COPY TO STDOUT` (Joachim Wieland)
- Add regression tests (Joachim Wieland, Michael)
- Major source code cleanups (Joachim Wieland, Michael)

E.127.3.15. Windows Port

- Allow MSVC to compile the PostgreSQL server (Magnus, Hiroshi Saito)

- Add MSVC support for utility commands and pg_dump (Hiroshi Saito)
- Add support for Windows code pages `1253`, `1254`, `1255`, and `1257` (Kris Jurka)
- Drop privileges on startup, so that the server can be started from an administrative account (Magnus)
- Stability fixes (Qingqing Zhou, Magnus)
- Add native semaphore implementation (Qingqing Zhou)

  The previous code mimicked SysV semaphores.

E.127.3.16. Source Code Changes

- Add GIN (Generalized Inverted iNdex) index access method (Teodor, Oleg)
- Remove R-tree indexing (Tom)

  Rtree has been re-implemented using GiST. Among other differences, this means that rtree indexes now have support for crash recovery via write-ahead logging (WAL).
- Reduce libraries needlessly linked into the backend (Martijn van Oosterhout, Tom)
- Add a configure flag to allow libedit to be preferred over GNU readline (Bruce)

  Use configure `--with-libedit-preferred`.
- Allow installation into directories containing spaces (Peter)
- Improve ability to relocate installation directories (Tom)
- Add support for Solaris x86_64 using the Solaris compiler (Pierre Girard, Theo Schlossnagle, Bruce)
- Add DTrace support (Robert Lor)
- Add `PG_VERSION_NUM` for use by third-party applications wanting to test the backend version in C using $>$ and $<$ comparisons (Bruce)
- Add `XLOG_BLCKSZ` as independent from `BLCKSZ` (Mark Wong)
- Add `LWLOCK_STATS` define to report locking activity (Tom)
- Emit warnings for unknown configure options (Martijn van Oosterhout)
- Add server support for "plugin" libraries that can be used for add-on tasks such as debugging and performance measurement (Korry Douglas)

  This consists of two features: a table of "rendezvous variables" that allows separately-loaded shared libraries to communicate, and a new configuration parameter `local_preload_libraries` that allows libraries to be loaded into specific sessions without explicit cooperation from the client application. This allows external add-ons to implement features such as a PL/pgSQL debugger.
- Rename existing configuration parameter `preload_libraries` to `shared_preload_libraries` (Tom)

  This was done for clarity in comparison to `local_preload_libraries`.
- Add new configuration parameter `server_version_num` (Greg Sabino Mullane)

  This is like `server_version`, but is an integer, e.g. `80200`. This allows applications to make version checks more easily.
- Add a configuration parameter `seq_page_cost` (Tom)

- Re-implement the regression test script as a C program (Magnus, Tom)
- Allow loadable modules to allocate shared memory and lightweight locks (Marc Munro)
- Add automatic initialization and finalization of dynamically loaded libraries (Ralf Engelschall, Tom)

  New functions `_PG_init()` and `_PG_fini()` are called if the library defines such symbols. Hence we no longer need to specify an initialization function in `shared_preload_libraries`; we can assume that the library used the `_PG_init()` convention instead.
- Add `PG_MODULE_MAGIC` header block to all shared object files (Martijn van Oosterhout)

  The magic block prevents version mismatches between loadable object files and servers.
- Add shared library support for AIX (Laurenz Albe)
- New XML documentation section (Bruce)

E.127.3.17. Contrib Changes

- Major tsearch2 improvements (Oleg, Teodor)
  - multibyte encoding support, including UTF8
  - query rewriting support
  - improved ranking functions
  - thesaurus dictionary support
  - Ispell dictionaries now recognize MySpell format, used by OpenOffice
  - GIN support

- Add adminpack module containing Pgadmin administration functions (Dave)

  These functions provide additional file system access routines not present in the default PostgreSQL server.
- Add sslinfo module (Victor Wagner)

  Reports information about the current connection's SSL certificate.
- Add pgrowlocks module (Tatsuo)

  This shows row locking information for a specified table.
- Add hstore module (Oleg, Teodor)
- Add isn module, replacing isbn_issn (Jeremy Kronuz)

  This new implementation supports EAN13, UPC, ISBN (books), ISMN (music), and ISSN (serials).
- Add index information functions to pgstattuple (ITAGAKI Takahiro, Satoshi Nagayasu)
- Add pg_freespacemap module to display free space map information (Mark Kirkwood)
- pgcrypto now has all planned functionality (Marko Kreen)
  - Include iMath library in pgcrypto to have the public-key encryption functions always available.
  - Add SHA224 algorithm that was missing in OpenBSD code.

- Activate builtin code for SHA224/256/384/512 hashes on older OpenSSL to have those algorithms always available.
- New function gen_random_bytes() that returns cryptographically strong randomness. Useful for generating encryption keys.
- Remove digest_exists(), hmac_exists() and cipher_exists() functions.

- Improvements to cube module (Joshua Reich)

  New functions are `cube(float[])`, `cube(float[], float[])`, and `cube_subset(cube, int4[])`.
- Add async query capability to dblink (Kai Londenberg, Joe Conway)
- New operators for array-subset comparisons (`@>`, `<@`, `&&`) (Tom)

  Various contrib packages already had these operators for their datatypes, but the naming wasn't consistent. We have now added consistently named array-subset comparison operators to the core code and all the contrib packages that have such functionality. (The old names remain available, but are deprecated.)
- Add uninstall scripts for all contrib packages that have install scripts (David, Josh Drake)

E.128. Release 8.1.23

Release Date: 2010-12-16

This release contains a variety of fixes from 8.1.22. For information about new features in the 8.1 major release, see Section E.151.

This is expected to be the last PostgreSQL release in the 8.1.X series. Users are encouraged to update to a newer release branch soon.

E.128.1. Migration to Version 8.1.23

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.18, see Section E.133.

E.128.2. Changes

- Force the default `wal_sync_method` to be `fdatasync` on Linux (Tom Lane, Marti Raudsepp)

  The default on Linux has actually been `fdatasync` for many years, but recent kernel changes caused PostgreSQL to choose `open_datasync` instead. This choice did not result in any performance improvement, and caused outright failures on certain filesystems, notably `ext4` with the `data=journal` mount option.

- Fix recovery from base backup when the starting checkpoint WAL record is not in the same WAL segment as its redo point (Jeff Davis)
- Add support for detecting register-stack overrun on `IA64` (Tom Lane)

  The `IA64` architecture has two hardware stacks. Full prevention of stack-overrun failures requires checking both.
- Add a check for stack overflow in `copyObject()` (Tom Lane)

  Certain code paths could crash due to stack overflow given a sufficiently complex query.
- Fix detection of page splits in temporary GiST indexes (Heikki Linnakangas)

  It is possible to have a "concurrent" page split in a temporary index, if for example there is an open cursor scanning the index when an insertion is done. GiST failed to detect this case and hence could deliver wrong results when execution of the cursor continued.
- Avoid memory leakage while `ANALYZE`'ing complex index expressions (Tom Lane)
- Ensure an index that uses a whole-row Var still depends on its table (Tom Lane)

  An index declared like `create index i on t (foo(t.*))` would not automatically get dropped when its table was dropped.
- Do not "inline" a SQL function with multiple `OUT` parameters (Tom Lane)

  This avoids a possible crash due to loss of information about the expected result rowtype.
- Fix constant-folding of `COALESCE()` expressions (Tom Lane)

  The planner would sometimes attempt to evaluate sub-expressions that in fact could never be reached, possibly leading to unexpected errors.
- Add print functionality for `InhRelation` nodes (Tom Lane)

  This avoids a failure when `debug_print_parse` is enabled and certain types of query are executed.
- Fix incorrect calculation of distance from a point to a horizontal line segment (Tom Lane)

  This bug affected several different geometric distance-measurement operators.
- Fix PL/pgSQL's handling of "simple" expressions to not fail in recursion or error-recovery cases (Tom Lane)
- Fix bug in `contrib/cube`'s GiST picksplit algorithm (Alexander Korotkov)

  This could result in considerable inefficiency, though not actually incorrect answers, in a GiST index on a `cube` column. If you have such an index, consider `REINDEX`ing it after installing this update.
- Don't emit "identifier will be truncated" notices in `contrib/dblink` except when creating new connections (Itagaki Takahiro)
- Fix potential coredump on missing public key in `contrib/pgcrypto` (Marti Raudsepp)
- Fix memory leak in `contrib/xml2`'s XPath query functions (Tom Lane)
- Update time zone data files to tzdata release 2010o for DST law changes in Fiji and Samoa; also historical corrections for Hong Kong.

E.129. Release 8.1.22

Release Date: 2010-10-04

This release contains a variety of fixes from 8.1.21. For information about new features in the 8.1 major release, see Section E.151.

The PostgreSQL community will stop releasing updates for the 8.1.X release series in November 2010. Users are encouraged to update to a newer release branch soon.

E.129.1. Migration to Version 8.1.22

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.18, see Section E.133.

E.129.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

  It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

  Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)

- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.

- Prevent show_session_authorization() from crashing within autovacuum processes (Tom Lane)

- Defend against functions returning setof record where not all the returned rows are actually of the same rowtype (Tom Lane)

- Fix possible failure when hashing a pass-by-reference function result (Tao Ma, Tom Lane)

- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.

- Avoid recursion while assigning XIDs to heavily-nested subtransactions (Andres Freund, Robert Haas)

  The original coding could result in a crash if there was limited stack space.

- Fix `log_line_prefix`'s `%i` escape, which could produce junk early in backend startup (Tom Lane)
- Fix possible data corruption in `ALTER TABLE ... SET TABLESPACE` when archiving is enabled (Jeff Davis)
- Allow `CREATE DATABASE` and `ALTER DATABASE ... SET TABLESPACE` to be interrupted by query-cancel (Guillaume Lelarge)
- In PL/Python, defend against null pointer results from `PyCObject_AsVoidPtr` and `PyCObject_FromVoidPtr` (Peter Eisentraut)
- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)
- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)
- Fix `contrib/dblink` to handle connection names longer than 62 bytes correctly (Itagaki Takahiro)
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)
- Update time zone data files to tzdata release 2010l for DST law changes in Egypt and Palestine; also historical corrections for Finland.

  This change also adds new names for two Micronesian timezones: Pacific/Chuuk is now preferred over Pacific/Truk (and the preferred abbreviation is CHUT not TRUT) and Pacific/Pohnpei is preferred over Pacific/Ponape.

E.130. Release 8.1.21

Release Date: 2010-05-17

This release contains a variety of fixes from 8.1.20. For information about new features in the 8.1 major release, see Section E.151.

E.130.1. Migration to Version 8.1.21

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.18, see Section E.133.

E.130.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b` variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

  Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

  In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)

- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)

- Prevent infinite recursion in psql when expanding a variable that refers to itself (Tom)

- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)

- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.

- Update time zone data files to tzdata release 2010j for DST law changes in Argentina, Australian Antarctic, Bangladesh, Mexico, Morocco, Pakistan, Palestine, Russia, Syria, Tunisia; also historical corrections for Taiwan.

E.131. Release 8.1.20

Release Date: 2010-03-15

This release contains a variety of fixes from 8.1.19. For information about new features in the 8.1 major release, see Section E.151.

E.131.1. Migration to Version 8.1.20

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.18, see Section E.133.

E.131.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.

- Fix possible crashes when trying to recover from a failure in subtransaction start (Tom)

- Fix server memory leak associated with use of savepoints and a client encoding different from server's encoding (Tom)

- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).

- Fix integer-to-bit-string conversions to handle the first fractional byte correctly when the output bit width is wider than the given integer by something other than a multiple of 8 bits (Tom)

- Fix some cases of pathologically slow regular expression matching (Tom)

- Fix the `STOP WAL LOCATION` entry in backup history files to report the next WAL segment's name when the end location is exactly at a segment boundary (Itagaki Takahiro)

- Fix some more cases of temporary-file leakage (Heikki)

  This corrects a problem introduced in the previous minor release. One case that failed is when a plpgsql function returning set is called within another function's exception handler.

- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.

- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)

- Fix psql's `numericlocale` option to not format strings it shouldn't in latex and troff output formats (Heikki)

- Fix plpgsql failure in one case where a composite column is set to NULL (Tom)

- Add `volatile` markings in PL/Python to avoid possible compiler-specific misbehavior (Zdenek Kotala)
- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

  The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.
- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)
- Fix assorted crashes in `contrib/xml2` caused by sloppy memory management (Tom)
- Update time zone data files to tzdata release 2010e for DST law changes in Bangladesh, Chile, Fiji, Mexico, Paraguay, Samoa.

E.132. Release 8.1.19

Release Date: 2009-12-14

This release contains a variety of fixes from 8.1.18. For information about new features in the 8.1 major release, see Section E.151.

E.132.1. Migration to Version 8.1.19

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.18, see Section E.133.

E.132.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).
- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).
- Fix possible crash during backend-startup-time cache initialization (Tom)
- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.
- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.

- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)
- Ensure that shared tuple-level locks held by prepared transactions are not ignored (Heikki)
- Fix premature drop of temporary files used for a cursor that is accessed within a subtransaction (Heikki)
- Fix PAM password processing to be more robust (Tom)

  The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.
- Fix processing of ownership dependencies during `CREATE OR REPLACE FUNCTION` (Tom)
- Ensure that Perl arrays are properly converted to PostgreSQL arrays when returned by a set-returning PL/Perl function (Andrew Dunstan, Abhijit Menon-Sen)

  This worked correctly already for non-set-returning functions.
- Fix rare crash in exception processing in PL/Python (Peter)
- Ensure psql's flex module is compiled with the correct system header definitions (Tom)

  This fixes build failures on platforms where `--enable-largefile` causes incompatible changes in the generated code.
- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)
- Update time zone data files to tzdata release 2009s for DST law changes in Antarctica, Argentina, Bangladesh, Fiji, Novokuznetsk, Pakistan, Palestine, Samoa, Syria; also historical corrections for Hong Kong.

E.133. Release 8.1.18

Release Date: 2009-09-09

This release contains a variety of fixes from 8.1.17. For information about new features in the 8.1 major release, see Section E.151.

E.133.1. Migration to Version 8.1.18

A dump/restore is not required for those running 8.1.X. However, if you have any hash indexes on `interval` columns, you must `REINDEX` them after updating to 8.1.18. Also, if you are upgrading from a version earlier than 8.1.15, see Section E.136.

E.133.2. Changes

- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)

- Fix handling of sub-SELECTs appearing in the arguments of an outer-level aggregate function (Tom)
- Fix hash calculation for data type `interval` (Tom)

  This corrects wrong results for hash joins on interval values. It also changes the contents of hash indexes on interval columns. If you have any such indexes, you must `REINDEX` them after updating.
- Treat `to_char(..., 'TH')` as an uppercase ordinal suffix with `'HH'`/`'HH12'` (Heikki)

  It was previously handled as `'th'` (lowercase).
- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Fix calculation of distance between a point and a line segment (Tom)

  This led to incorrect results from a number of geometric operators.
- Fix `money` data type to work in locales where currency amounts have no fractional digits, e.g. Japan (Itagaki Takahiro)
- Properly round datetime input like `00:12:57.9999999999999999999999999999` (Tom)
- Fix poor choice of page split point in GiST R-tree operator classes (Teodor)
- Fix portability issues in plperl initialization (Andrew Dunstan)
- Fix pg_ctl to not go into an infinite loop if `postgresql.conf` is empty (Jeff Davis)
- Fix `contrib/xml2`'s `xslt_process()` to properly handle the maximum number of parameters (twenty) (Tom)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)
- Update time zone data files to tzdata release 2009l for DST law changes in Bangladesh, Egypt, Jordan, Pakistan, Argentina/San_Luis, Cuba, Jordan (historical correction only), Mauritius, Morocco, Palestine, Syria, Tunisia.

E.134. Release 8.1.17

Release Date: 2009-03-16

This release contains a variety of fixes from 8.1.16. For information about new features in the 8.1 major release, see Section E.151.

E.134.1. Migration to Version 8.1.17

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.15, see Section E.136.

E.134.2. Changes

- Prevent error recursion crashes when encoding conversion fails (Tom)

  This change extends fixes made in the last two minor releases for related failure scenarios. The previous fixes were narrowly tailored for the original problem reports, but we have now recognized that *any* error thrown by an encoding conversion function could potentially lead to infinite recursion while trying to report the error. The solution therefore is to disable translation and encoding conversion and report the plain-ASCII form of any error message, if we find we have gotten into a recursive error reporting situation. (CVE-2009-0922)

- Disallow `CREATE CONVERSION` with the wrong encodings for the specified conversion function (Heikki)

  This prevents one possible scenario for encoding conversion failure. The previous change is a backstop to guard against other kinds of failures in the same area.

- Fix core dump when `to_char()` is given format codes that are inappropriate for the type of the data argument (Tom)

- Fix decompilation of `CASE WHEN` with an implicit coercion (Tom)

  This mistake could lead to Assert failures in an Assert-enabled build, or an "unexpected CASE WHEN clause" error message in other cases, when trying to examine or dump a view.

- Fix possible misassignment of the owner of a TOAST table's rowtype (Tom)

  If `CLUSTER` or a rewriting variant of `ALTER TABLE` were executed by someone other than the table owner, the `pg_type` entry for the table's TOAST table would end up marked as owned by that someone. This caused no immediate problems, since the permissions on the TOAST rowtype aren't examined by any ordinary database operation. However, it could lead to unexpected failures if one later tried to drop the role that issued the command (in 8.1 or 8.2), or "owner of data type appears to be invalid" warnings from pg_dump after having done so (in 8.3).

- Clean up PL/pgSQL error status variables fully at block exit (Ashesh Vashi and Dave Page)

  This is not a problem for PL/pgSQL itself, but the omission could cause the PL/pgSQL Debugger to crash while examining the state of a function.

- Add `MUST` (Mauritius Island Summer Time) to the default list of known timezone abbreviations (Xavier Bugaud)

E.135. Release 8.1.16

Release Date: 2009-02-02

This release contains a variety of fixes from 8.1.15. For information about new features in the 8.1 major release, see Section E.151.

E.135.1. Migration to Version 8.1.16

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.15, see Section E.136.

E.135.2. Changes

- Fix crash in autovacuum (Alvaro)

  The crash occurs only after vacuuming a whole database for anti-transaction-wraparound purposes, which means that it occurs infrequently and is hard to track down.
- Improve handling of URLs in `headline()` function (Teodor)
- Improve handling of overlength headlines in `headline()` function (Teodor)
- Prevent possible Assert failure or misconversion if an encoding conversion is created with the wrong conversion function for the specified pair of encodings (Tom, Heikki)
- Avoid unnecessary locking of small tables in `VACUUM` (Heikki)
- Ensure that the contents of a holdable cursor don't depend on the contents of TOAST tables (Tom)

  Previously, large field values in a cursor result might be represented as TOAST pointers, which would fail if the referenced table got dropped before the cursor is read, or if the large value is deleted and then vacuumed away. This cannot happen with an ordinary cursor, but it could with a cursor that is held past its creating transaction.
- Fix uninitialized variables in `contrib/tsearch2`'s `get_covers()` function (Teodor)
- Fix configure script to properly report failure when unable to obtain linkage information for PL/Perl (Andrew)
- Make all documentation reference `pgsql-bugs` and/or `pgsql-hackers` as appropriate, instead of the now-decommissioned `pgsql-ports` and `pgsql-patches` mailing lists (Tom)
- Update time zone data files to tzdata release 2009a (for Kathmandu and historical DST corrections in Switzerland, Cuba)

E.136. Release 8.1.15

Release Date: 2008-11-03

This release contains a variety of fixes from 8.1.14. For information about new features in the 8.1 major release, see Section E.151.

E.136.1. Migration to Version 8.1.15

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149. Also, if you were running a previous 8.1.X release, it is recommended to `REINDEX` all GiST indexes after the upgrade.

E.136.2. Changes

- Fix GiST index corruption due to marking the wrong index entry "dead" after a deletion (Teodor)

This would result in index searches failing to find rows they should have found. Corrupted indexes can be fixed with `REINDEX`.

- Fix backend crash when the client encoding cannot represent a localized error message (Tom)

  We have addressed similar issues before, but it would still fail if the "character has no equivalent" message itself couldn't be converted. The fix is to disable localization and send the plain ASCII error message when we detect such a situation.

- Fix possible crash when deeply nested functions are invoked from a trigger (Tom)

- Fix mis-expansion of rule queries when a sub-`SELECT` appears in a function call in `FROM`, a multi-row `VALUES` list, or a `RETURNING` list (Tom)

  The usual symptom of this problem is an "unrecognized node type" error.

- Ensure an error is reported when a newly-defined PL/pgSQL trigger function is invoked as a normal function (Tom)

- Prevent possible collision of `relfilenode` numbers when moving a table to another tablespace with `ALTER SET TABLESPACE` (Heikki)

  The command tried to re-use the existing filename, instead of picking one that is known unused in the destination directory.

- Fix incorrect tsearch2 headline generation when single query item matches first word of text (Sushant Sinha)

- Fix improper display of fractional seconds in interval values when using a non-ISO datestyle in an `--enable-integer-datetimes` build (Ron Mayer)

- Ensure `SPI_getvalue` and `SPI_getbinval` behave correctly when the passed tuple and tuple descriptor have different numbers of columns (Tom)

  This situation is normal when a table has had columns added or removed, but these two functions didn't handle it properly. The only likely consequence is an incorrect error indication.

- Fix ecpg's parsing of `CREATE ROLE` (Michael)

- Fix recent breakage of `pg_ctl restart` (Tom)

- Update time zone data files to tzdata release 2008i (for DST law changes in Argentina, Brazil, Mauritius, Syria)

E.137. Release 8.1.14

Release Date: 2008-09-22

This release contains a variety of fixes from 8.1.13. For information about new features in the 8.1 major release, see Section E.151.

E.137.1. Migration to Version 8.1.14

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.137.2. Changes

- Widen local lock counters from 32 to 64 bits (Tom)

  This responds to reports that the counters could overflow in sufficiently long transactions, leading to unexpected "lock is already held" errors.

- Fix possible duplicate output of tuples during a GiST index scan (Teodor)

- Add checks in executor startup to ensure that the tuples produced by an `INSERT` or `UPDATE` will match the target table's current rowtype (Tom)

  `ALTER COLUMN TYPE`, followed by re-use of a previously cached plan, could produce this type of situation. The check protects against data corruption and/or crashes that could ensue.

- Fix `AT TIME ZONE` to first try to interpret its timezone argument as a timezone abbreviation, and only try it as a full timezone name if that fails, rather than the other way around as formerly (Tom)

  The timestamp input functions have always resolved ambiguous zone names in this order. Making `AT TIME ZONE` do so as well improves consistency, and fixes a compatibility bug introduced in 8.1: in ambiguous cases we now behave the same as 8.0 and before did, since in the older versions `AT TIME ZONE` accepted *only* abbreviations.

- Fix datetime input functions to correctly detect integer overflow when running on a 64-bit platform (Tom)

- Improve performance of writing very long log messages to syslog (Tom)

- Fix bug in backwards scanning of a cursor on a `SELECT DISTINCT ON` query (Tom)

- Fix planner bug with nested sub-select expressions (Tom)

  If the outer sub-select has no direct dependency on the parent query, but the inner one does, the outer value might not get recalculated for new parent query rows.

- Fix planner to estimate that `GROUP BY` expressions yielding boolean results always result in two groups, regardless of the expressions' contents (Tom)

  This is very substantially more accurate than the regular `GROUP BY` estimate for certain boolean tests like *`col`* `IS NULL`.

- Fix PL/pgSQL to not fail when a `FOR` loop's target variable is a record containing composite-type fields (Tom)

- Fix PL/Tcl to behave correctly with Tcl 8.5, and to be more careful about the encoding of data sent to or from Tcl (Tom)

- Fix PL/Python to work with Python 2.5

  This is a back-port of fixes made during the 8.2 development cycle.

- Improve pg_dump and pg_restore's error reporting after failure to send a SQL command (Tom)

- Fix pg_ctl to properly preserve postmaster command-line arguments across a `restart` (Bruce)

- Update time zone data files to tzdata release 2008f (for DST law changes in Argentina, Bahamas, Brazil, Mauritius, Morocco, Pakistan, Palestine, and Paraguay)

E.138. Release 8.1.13

Release Date: 2008-06-12

This release contains one serious and one minor bug fix over 8.1.12. For information about new features in the 8.1 major release, see Section E.151.

E.138.1. Migration to Version 8.1.13

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.138.2. Changes

- Make `pg_get_ruledef()` parenthesize negative constants (Tom)

  Before this fix, a negative constant in a view or rule might be dumped as, say, `-42::integer`, which is subtly incorrect: it should be `(-42)::integer` due to operator precedence rules. Usually this would make little difference, but it could interact with another recent patch to cause PostgreSQL to reject what had been a valid `SELECT DISTINCT` view query. Since this could result in pg_dump output failing to reload, it is being treated as a high-priority fix. The only released versions in which dump output is actually incorrect are 8.3.1 and 8.2.7.

- Make `ALTER AGGREGATE ... OWNER TO` update `pg_shdepend` (Tom)

  This oversight could lead to problems if the aggregate was later involved in a `DROP OWNED` or `REASSIGN OWNED` operation.

E.139. Release 8.1.12

Release Date: never released

This release contains a variety of fixes from 8.1.11. For information about new features in the 8.1 major release, see Section E.151.

E.139.1. Migration to Version 8.1.12

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.139.2. Changes

- Fix `ALTER TABLE ADD COLUMN ... PRIMARY KEY` so that the new column is correctly checked to see if it's been initialized to all non-nulls (Brendan Jurd)

  Previous versions neglected to check this requirement at all.

- Fix possible `CREATE TABLE` failure when inheriting the "same" constraint from multiple parent relations that inherited that constraint from a common ancestor (Tom)

- Fix conversions between ISO-8859-5 and other encodings to handle Cyrillic "Yo" characters (`e` and `E` with two dots) (Sergey Burladyan)

- Fix a few datatype input functions that were allowing unused bytes in their results to contain uninitialized, unpredictable values (Tom)

  This could lead to failures in which two apparently identical literal values were not seen as equal, resulting in the parser complaining about unmatched `ORDER BY` and `DISTINCT` expressions.

- Fix a corner case in regular-expression substring matching (`substring(`*`string`* `from` *`pattern`*`)`) (Tom)

  The problem occurs when there is a match to the pattern overall but the user has specified a parenthesized subexpression and that subexpression hasn't got a match. An example is `substring('foo' from 'foo(bar)?')`. This should return NULL, since `(bar)` isn't matched, but it was mistakenly returning the whole-pattern match instead (ie, `foo`).

- Update time zone data files to tzdata release 2008c (for DST law changes in Morocco, Iraq, Choibalsan, Pakistan, Syria, Cuba, Argentina/San_Luis, and Chile)

- Fix incorrect result from ecpg's `PGTYPEStimestamp_sub()` function (Michael)

- Fix core dump in `contrib/xml2`'s `xpath_table()` function when the input query returns a NULL value (Tom)

- Fix `contrib/xml2`'s makefile to not override `CFLAGS` (Tom)

- Fix `DatumGetBool` macro to not fail with gcc 4.3 (Tom)

  This problem affects "old style" (V0) C functions that return boolean. The fix is already in 8.3, but the need to back-patch it was not realized at the time.

- Fix longstanding `LISTEN`/`NOTIFY` race condition (Tom)

  In rare cases a session that had just executed a `LISTEN` might not get a notification, even though one would be expected because the concurrent transaction executing `NOTIFY` was observed to commit later.

  A side effect of the fix is that a transaction that has executed a not-yet-committed `LISTEN` command will not see any row in `pg_listener` for the `LISTEN`, should it choose to look; formerly it would have. This behavior was never documented one way or the other, but it is possible that some applications depend on the old behavior.

- Disallow `LISTEN` and `UNLISTEN` within a prepared transaction (Tom)

  This was formerly allowed but trying to do it had various unpleasant consequences, notably that the originating backend could not exit as long as an `UNLISTEN` remained uncommitted.

- Fix rare crash when an error occurs during a query using a hash index (Heikki)

- Fix input of datetime values for February 29 in years BC (Tom)

  The former coding was mistaken about which years were leap years.

- Fix "unrecognized node type" error in some variants of `ALTER OWNER` (Tom)
- Fix pg_ctl to correctly extract the postmaster's port number from command-line options (Itagaki Takahiro, Tom)

  Previously, `pg_ctl start -w` could try to contact the postmaster on the wrong port, leading to bogus reports of startup failure.
- Use `-fwrapv` to defend against possible misoptimization in recent gcc versions (Tom)

  This is known to be necessary when building PostgreSQL with gcc 4.3 or later.
- Fix display of constant expressions in `ORDER BY` and `GROUP BY` (Tom)

  An explicitly casted constant would be shown incorrectly. This could for example lead to corruption of a view definition during dump and reload.
- Fix libpq to handle NOTICE messages correctly during COPY OUT (Tom)

  This failure has only been observed to occur when a user-defined datatype's output routine issues a NOTICE, but there is no guarantee it couldn't happen due to other causes.

E.140. Release 8.1.11

Release Date: 2008-01-07

This release contains a variety of fixes from 8.1.10, including fixes for significant security issues. For information about new features in the 8.1 major release, see Section E.151.

This is the last 8.1.X release for which the PostgreSQL community will produce binary packages for Windows. Windows users are encouraged to move to 8.2.X or later, since there are Windows-specific fixes in 8.2.X that are impractical to back-port. 8.1.X will continue to be supported on other platforms.

E.140.1. Migration to Version 8.1.11

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.140.2. Changes

- Prevent functions in indexes from executing with the privileges of the user running `VACUUM`, `ANALYZE`, etc (Tom)

  Functions used in index expressions and partial-index predicates are evaluated whenever a new table entry is made. It has long been understood that this poses a risk of trojan-horse code execution if one modifies a table owned by an untrustworthy user. (Note that triggers, defaults, check constraints, etc. pose the same type of risk.) But functions in indexes pose extra danger because they will be executed by routine maintenance operations such as `VACUUM FULL`, which are commonly performed automatically under a superuser account. For example, a nefarious user can execute code with superuser privileges by setting up a trojan-horse index definition and waiting for the next routine vacuum. The fix arranges for standard maintenance operations (including `VACUUM`,

ANALYZE, REINDEX, and CLUSTER) to execute as the table owner rather than the calling user, using the same privilege-switching mechanism already used for SECURITY DEFINER functions. To prevent bypassing this security measure, execution of SET SESSION AUTHORIZATION and SET ROLE is now forbidden within a SECURITY DEFINER context. (CVE-2007-6600)

- Repair assorted bugs in the regular-expression package (Tom, Will Drewry)

  Suitably crafted regular-expression patterns could cause crashes, infinite or near-infinite looping, and/or massive memory consumption, all of which pose denial-of-service hazards for applications that accept regex search patterns from untrustworthy sources. (CVE-2007-4769, CVE-2007-4772, CVE-2007-6067)

- Require non-superusers who use /contrib/dblink to use only password authentication, as a security measure (Joe)

  The fix that appeared for this in 8.1.10 was incomplete, as it plugged the hole for only some dblink functions. (CVE-2007-6601, CVE-2007-3278)

- Update time zone data files to tzdata release 2007k (in particular, recent Argentina changes) (Tom)
- Improve planner's handling of LIKE/regex estimation in non-C locales (Tom)
- Fix planner failure in some cases of WHERE false AND var IN (SELECT ...) (Tom)
- Preserve the tablespace of indexes that are rebuilt by ALTER TABLE ... ALTER COLUMN TYPE (Tom)
- Make archive recovery always start a new WAL timeline, rather than only when a recovery stop time was used (Simon)

  This avoids a corner-case risk of trying to overwrite an existing archived copy of the last WAL segment, and seems simpler and cleaner than the original definition.

- Make VACUUM not use all of maintenance_work_mem when the table is too small for it to be useful (Alvaro)
- Fix potential crash in translate() when using a multibyte database encoding (Tom)
- Fix overflow in extract(epoch from interval) for intervals exceeding 68 years (Tom)
- Fix PL/Perl to not fail when a UTF-8 regular expression is used in a trusted function (Andrew)
- Fix PL/Perl to cope when platform's Perl defines type bool as int rather than char (Tom)

  While this could theoretically happen anywhere, no standard build of Perl did things this way ... until Mac OS X 10.5.

- Fix PL/Python to not crash on long exception messages (Alvaro)
- Fix pg_dump to correctly handle inheritance child tables that have default expressions different from their parent's (Tom)
- Fix libpq crash when PGPASSFILE refers to a file that is not a plain file (Martin Pitt)
- ecpg parser fixes (Michael)
- Make contrib/pgcrypto defend against OpenSSL libraries that fail on keys longer than 128 bits; which is the case at least on some Solaris versions (Marko Kreen)
- Make contrib/tablefunc's crosstab() handle NULL rowid as a category in its own right, rather than crashing (Joe)
- Fix tsvector and tsquery output routines to escape backslashes correctly (Teodor, Bruce)
- Fix crash of to_tsvector() on huge input strings (Teodor)
- Require a specific version of Autoconf to be used when re-generating the configure script (Peter)

This affects developers and packagers only. The change was made to prevent accidental use of untested combinations of Autoconf and PostgreSQL versions. You can remove the version check if you really want to use a different Autoconf version, but it's your responsibility whether the result works or not.

E.141. Release 8.1.10

Release Date: 2007-09-17

This release contains a variety of fixes from 8.1.9. For information about new features in the 8.1 major release, see Section E.151.

E.141.1. Migration to Version 8.1.10

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.141.2. Changes

- Prevent index corruption when a transaction inserts rows and then aborts close to the end of a concurrent `VACUUM` on the same table (Tom)
- Make `CREATE DOMAIN ... DEFAULT NULL` work properly (Tom)
- Allow the `interval` data type to accept input consisting only of milliseconds or microseconds (Neil)
- Speed up rtree index insertion (Teodor)
- Fix excessive logging of SSL error messages (Tom)
- Fix logging so that log messages are never interleaved when using the syslogger process (Andrew)
- Fix crash when `log_min_error_statement` logging runs out of memory (Tom)
- Fix incorrect handling of some foreign-key corner cases (Tom)
- Prevent `REINDEX` and `CLUSTER` from failing due to attempting to process temporary tables of other sessions (Alvaro)
- Update the time zone database rules, particularly New Zealand's upcoming changes (Tom)
- Windows socket improvements (Magnus)
- Suppress timezone name (`%Z`) in log timestamps on Windows because of possible encoding mismatches (Tom)
- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

E.142. Release 8.1.9

Release Date: 2007-04-23

This release contains a variety of fixes from 8.1.8, including a security fix. For information about new features in the 8.1 major release, see Section E.151.

E.142.1. Migration to Version 8.1.9

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.142.2. Changes

- Support explicit placement of the temporary-table schema within `search_path`, and disable searching it for functions and operators (Tom)

  This is needed to allow a security-definer function to set a truly secure value of `search_path`. Without it, an unprivileged SQL user can use temporary objects to execute code with the privileges of the security-definer function (CVE-2007-2138). See `CREATE FUNCTION` for more information.
- `/contrib/tsearch2` crash fixes (Teodor)
- Require `COMMIT PREPARED` to be executed in the same database as the transaction was prepared in (Heikki)
- Fix potential-data-corruption bug in how `VACUUM FULL` handles `UPDATE` chains (Tom, Pavan Deolasee)
- Planner fixes, including improving outer join and bitmap scan selection logic (Tom)
- Fix PANIC during enlargement of a hash index (bug introduced in 8.1.6) (Tom)
- Fix POSIX-style timezone specs to follow new USA DST rules (Tom)

E.143. Release 8.1.8

Release Date: 2007-02-07

This release contains one fix from 8.1.7. For information about new features in the 8.1 major release, see Section E.151.

E.143.1. Migration to Version 8.1.8

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.143.2. Changes

- Remove overly-restrictive check for type length in constraints and functional indexes(Tom)

E.144. Release 8.1.7

Release Date: 2007-02-05

This release contains a variety of fixes from 8.1.6, including a security fix. For information about new features in the 8.1 major release, see Section E.151.

E.144.1. Migration to Version 8.1.7

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.144.2. Changes

- Remove security vulnerabilities that allowed connected users to read backend memory (Tom)

  The vulnerabilities involve suppressing the normal check that a SQL function returns the data type it's declared to, and changing the data type of a table column (CVE-2007-0555, CVE-2007-0556). These errors can easily be exploited to cause a backend crash, and in principle might be used to read database content that the user should not be able to access.
- Fix rare bug wherein btree index page splits could fail due to choosing an infeasible split point (Heikki Linnakangas)
- Improve `VACUUM` performance for databases with many tables (Tom)
- Fix autovacuum to avoid leaving non-permanent transaction IDs in non-connectable databases (Alvaro)

  This bug affects the 8.1 branch only.
- Fix for rare Assert() crash triggered by `UNION` (Tom)
- Tighten security of multi-byte character processing for UTF8 sequences over three bytes long (Tom)
- Fix bogus "permission denied" failures occurring on Windows due to attempts to fsync already-deleted files (Magnus, Tom)
- Fix possible crashes when an already-in-use PL/pgSQL function is updated (Tom)

E.145. Release 8.1.6

Release Date: 2007-01-08

This release contains a variety of fixes from 8.1.5. For information about new features in the 8.1 major release, see Section E.151.

E.145.1. Migration to Version 8.1.6

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.145.2. Changes

- Improve handling of `getaddrinfo()` on AIX (Tom)

  This fixes a problem with starting the statistics collector, among other things.
- Fix pg_restore to handle a tar-format backup that contains large objects (blobs) with comments (Tom)
- Fix "failed to re-find parent key" errors in `VACUUM` (Tom)
- Clean out `pg_internal.init` cache files during server restart (Simon)

  This avoids a hazard that the cache files might contain stale data after PITR recovery.
- Fix race condition for truncation of a large relation across a gigabyte boundary by `VACUUM` (Tom)
- Fix bug causing needless deadlock errors on row-level locks (Tom)
- Fix bugs affecting multi-gigabyte hash indexes (Tom)
- Fix possible deadlock in Windows signal handling (Teodor)
- Fix error when constructing an `ARRAY[]` made up of multiple empty elements (Tom)
- Fix ecpg memory leak during connection (Michael)
- Fix for Darwin (OS X) compilation (Tom)
- `to_number()` and `to_char(numeric)` are now `STABLE`, not `IMMUTABLE`, for new initdb installs (Tom)

  This is because `lc_numeric` can potentially change the output of these functions.
- Improve index usage of regular expressions that use parentheses (Tom)

  This improves psql `\d` performance also.
- Update timezone database

  This affects Australian and Canadian daylight-savings rules in particular.

E.146. Release 8.1.5

Release Date: 2006-10-16

This release contains a variety of fixes from 8.1.4. For information about new features in the 8.1 major release, see Section E.151.

E.146.1. Migration to Version 8.1.5

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.146.2. Changes

- Disallow aggregate functions in `UPDATE` commands, except within sub-SELECTs (Tom)

  The behavior of such an aggregate was unpredictable, and in 8.1.X could cause a crash, so it has been disabled. The SQL standard does not allow this either.
- Fix core dump when an untyped literal is taken as ANYARRAY
- Fix core dump in duration logging for extended query protocol when a `COMMIT` or `ROLLBACK` is executed
- Fix mishandling of AFTER triggers when query contains a SQL function returning multiple rows (Tom)
- Fix `ALTER TABLE ... TYPE` to recheck `NOT NULL` for `USING` clause (Tom)
- Fix `string_to_array()` to handle overlapping matches for the separator string

  For example, `string_to_array('123xx456xxx789', 'xx')`.
- Fix `to_timestamp()` for `AM`/`PM` formats (Bruce)
- Fix autovacuum's calculation that decides whether `ANALYZE` is needed (Alvaro)
- Fix corner cases in pattern matching for psql's `\d` commands
- Fix index-corrupting bugs in /contrib/ltree (Teodor)
- Numerous robustness fixes in ecpg (Joachim Wieland)
- Fix backslash escaping in /contrib/dbmirror
- Minor fixes in /contrib/dblink and /contrib/tsearch2
- Efficiency improvements in hash tables and bitmap index scans (Tom)
- Fix instability of statistics collection on Windows (Tom, Andrew)
- Fix `statement_timeout` to use the proper units on Win32 (Bruce)

  In previous Win32 8.1.X versions, the delay was off by a factor of 100.
- Fixes for MSVC and Borland C++ compilers (Hiroshi Saito)
- Fixes for AIX and Intel compilers (Tom)
- Fix rare bug in continuous archiving (Tom)

E.147. Release 8.1.4

Release Date: 2006-05-23

This release contains a variety of fixes from 8.1.3, including patches for extremely serious security issues. For information about new features in the 8.1 major release, see Section E.151.

E.147.1. Migration to Version 8.1.4

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

Full security against the SQL-injection attacks described in CVE-2006-2313 and CVE-2006-2314 might require changes in application code. If you have applications that embed untrustworthy strings into SQL commands, you should examine them as soon as possible to ensure that they are using recommended escaping techniques. In most cases, applications should be using subroutines provided by libraries or drivers (such as libpq's `PQescapeStringConn()`) to perform string escaping, rather than relying on *ad hoc* code to do it.

E.147.2. Changes

- Change the server to reject invalidly-encoded multibyte characters in all cases (Tatsuo, Tom)

  While PostgreSQL has been moving in this direction for some time, the checks are now applied uniformly to all encodings and all textual input, and are now always errors not merely warnings. This change defends against SQL-injection attacks of the type described in CVE-2006-2313.

- Reject unsafe uses of `\'` in string literals

  As a server-side defense against SQL-injection attacks of the type described in CVE-2006-2314, the server now only accepts `''` and not `\'` as a representation of ASCII single quote in SQL string literals. By default, `\'` is rejected only when `client_encoding` is set to a client-only encoding (SJIS, BIG5, GBK, GB18030, or UHC), which is the scenario in which SQL injection is possible. A new configuration parameter `backslash_quote` is available to adjust this behavior when needed. Note that full security against CVE-2006-2314 might require client-side changes; the purpose of `backslash_quote` is in part to make it obvious that insecure clients are insecure.

- Modify libpq's string-escaping routines to be aware of encoding considerations and `standard_conforming_strings`

  This fixes libpq-using applications for the security issues described in CVE-2006-2313 and CVE-2006-2314, and also future-proofs them against the planned changeover to SQL-standard string literal syntax. Applications that use multiple PostgreSQL connections concurrently should migrate to `PQescapeStringConn()` and `PQescapeByteaConn()` to ensure that escaping is done correctly for the settings in use in each database connection. Applications that do string escaping "by hand" should be modified to rely on library routines instead.

- Fix weak key selection in pgcrypto (Marko Kreen)

  Errors in fortuna PRNG reseeding logic could cause a predictable session key to be selected by `pgp_sym_encrypt()` in some cases. This only affects non-OpenSSL-using builds.

- Fix some incorrect encoding conversion functions

`win1251_to_iso`, `win866_to_iso`, `euc_tw_to_big5`, `euc_tw_to_mic`, `mic_to_euc_tw` were all broken to varying extents.

- Clean up stray remaining uses of `\'` in strings (Bruce, Jan)
- Make autovacuum visible in `pg_stat_activity` (Alvaro)
- Disable `full_page_writes` (Tom)

  In certain cases, having `full_page_writes` off would cause crash recovery to fail. A proper fix will appear in 8.2; for now it's just disabled.
- Various planner fixes, particularly for bitmap index scans and MIN/MAX optimization (Tom)
- Fix incorrect optimization in merge join (Tom)

  Outer joins could sometimes emit multiple copies of unmatched rows.
- Fix crash from using and modifying a plpgsql function in the same transaction
- Fix WAL replay for case where a B-Tree index has been truncated
- Fix `SIMILAR TO` for patterns involving `|` (Tom)
- Fix `SELECT INTO` and `CREATE TABLE AS` to create tables in the default tablespace, not the base directory (Kris Jurka)
- Fix server to use custom DH SSL parameters correctly (Michael Fuhr)
- Improve qsort performance (Dann Corbit)

  Currently this code is only used on Solaris.
- Fix for OS/X Bonjour on x86 systems (Ashley Clark)
- Fix various minor memory leaks
- Fix problem with password prompting on some Win32 systems (Robert Kinberg)
- Improve pg_dump's handling of default values for domains
- Fix pg_dumpall to handle identically-named users and groups reasonably (only possible when dumping from a pre-8.1 server) (Tom)

  The user and group will be merged into a single role with `LOGIN` permission. Formerly the merged role wouldn't have `LOGIN` permission, making it unusable as a user.
- Fix pg_restore `-n` to work as documented (Tom)

E.148. Release 8.1.3

Release Date: 2006-02-14

This release contains a variety of fixes from 8.1.2, including one very serious security issue. For information about new features in the 8.1 major release, see Section E.151.

E.148.1. Migration to Version 8.1.3

A dump/restore is not required for those running 8.1.X. However, if you are upgrading from a version earlier than 8.1.2, see Section E.149.

E.148.2. Changes

- Fix bug that allowed any logged-in user to `SET ROLE` to any other database user id (CVE-2006-0553)

  Due to inadequate validity checking, a user could exploit the special case that `SET ROLE` normally uses to restore the previous role setting after an error. This allowed ordinary users to acquire superuser status, for example. The escalation-of-privilege risk exists only in 8.1.0-8.1.2. However, in all releases back to 7.3 there is a related bug in `SET SESSION AUTHORIZATION` that allows unprivileged users to crash the server, if it has been compiled with Asserts enabled (which is not the default). Thanks to Akio Ishida for reporting this problem.

- Fix bug with row visibility logic in self-inserted rows (Tom)

  Under rare circumstances a row inserted by the current command could be seen as already valid, when it should not be. Repairs bug created in 8.0.4, 7.4.9, and 7.3.11 releases.

- Fix race condition that could lead to "file already exists" errors during pg_clog and pg_subtrans file creation (Tom)

- Fix cases that could lead to crashes if a cache-invalidation message arrives at just the wrong time (Tom)

- Properly check `DOMAIN` constraints for `UNKNOWN` parameters in prepared statements (Neil)

- Ensure `ALTER COLUMN TYPE` will process `FOREIGN KEY`, `UNIQUE`, and `PRIMARY KEY` constraints in the proper order (Nakano Yoshihisa)

- Fixes to allow restoring dumps that have cross-schema references to custom operators or operator classes (Tom)

- Allow pg_restore to continue properly after a `COPY` failure; formerly it tried to treat the remaining `COPY` data as SQL commands (Stephen Frost)

- Fix pg_ctl `unregister` crash when the data directory is not specified (Magnus)

- Fix libpq `PQprint` HTML tags (Christoph Zwerschke)

- Fix ecpg crash on AMD64 and PPC (Neil)

- Allow `SETOF` and `%TYPE` to be used together in function result type declarations

- Recover properly if error occurs during argument passing in PL/python (Neil)

- Fix memory leak in `plperl_return_next` (Neil)

- Fix PL/perl's handling of locales on Win32 to match the backend (Andrew)

- Various optimizer fixes (Tom)

- Fix crash when `log_min_messages` is set to `DEBUG3` or above in `postgresql.conf` on Win32 (Bruce)

- Fix pgxs `-L` library path specification for Win32, Cygwin, OS X, AIX (Bruce)

- Check that SID is enabled while checking for Win32 admin privileges (Magnus)

- Properly reject out-of-range date inputs (Kris Jurka)

- Portability fix for testing presence of `finite` and `isinf` during configure (Tom)

- Improve speed of `COPY IN` via libpq, by avoiding a kernel call per data line (Alon Goldshuv)

- Improve speed of `/contrib/tsearch2` index creation (Tom)

E.149. Release 8.1.2

Release Date: 2006-01-09

This release contains a variety of fixes from 8.1.1. For information about new features in the 8.1 major release, see Section E.151.

E.149.1. Migration to Version 8.1.2

A dump/restore is not required for those running 8.1.X. However, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the locale or plperl issues described below.

E.149.2. Changes

- Fix Windows code so that postmaster will continue rather than exit if there is no more room in ShmemBackendArray (Magnus)

  The previous behavior could lead to a denial-of-service situation if too many connection requests arrive close together. This applies *only* to the Windows port.

- Fix bug introduced in 8.0 that could allow ReadBuffer to return an already-used page as new, potentially causing loss of recently-committed data (Tom)

- Fix for protocol-level Describe messages issued outside a transaction or in a failed transaction (Tom)

- Fix character string comparison for locales that consider different character combinations as equal, such as Hungarian (Tom)

  This might require `REINDEX` to fix existing indexes on textual columns.

- Set locale environment variables during postmaster startup to ensure that plperl won't change the locale later

  This fixes a problem that occurred if the postmaster was started with environment variables specifying a different locale than what initdb had been told. Under these conditions, any use of plperl was likely to lead to corrupt indexes. You might need `REINDEX` to fix existing indexes on textual columns if this has happened to you.

- Allow more flexible relocation of installation directories (Tom)

  Previous releases supported relocation only if all installation directory paths were the same except for the last component.

- Prevent crashes caused by the use of `ISO-8859-5` and `ISO-8859-9` encodings (Tatsuo)

- Fix longstanding bug in strpos() and regular expression handling in certain rarely used Asian multibyte character sets (Tatsuo)

- Fix bug where COPY CSV mode considered any `\.` to terminate the copy data

  The new code requires `\.` to appear alone on a line, as per documentation.

- Make COPY CSV mode quote a literal data value of `\.` to ensure it cannot be interpreted as the end-of-data marker (Bruce)

- Various fixes for functions returning RECORDs (Tom)
- Fix processing of postgresql.conf so a final line with no newline is processed properly (Tom)
- Fix bug in /contrib/pgcrypto gen_salt, which caused it not to use all available salt space for MD5 and XDES algorithms (Marko Kreen, Solar Designer)

  Salts for Blowfish and standard DES are unaffected.
- Fix autovacuum crash when processing expression indexes
- Fix /contrib/dblink to throw an error, rather than crashing, when the number of columns specified is different from what's actually returned by the query (Joe)

E.150. Release 8.1.1

Release Date: 2005-12-12

This release contains a variety of fixes from 8.1.0. For information about new features in the 8.1 major release, see Section E.151.

E.150.1. Migration to Version 8.1.1

A dump/restore is not required for those running 8.1.X.

E.150.2. Changes

- Fix incorrect optimizations of outer-join conditions (Tom)
- Fix problems with wrong reported column names in cases involving sub-selects flattened by the optimizer (Tom)
- Fix update failures in scenarios involving CHECK constraints, toasted columns, *and* indexes (Tom)
- Fix bgwriter problems after recovering from errors (Tom)

  The background writer was found to leak buffer pins after write errors. While not fatal in itself, this might lead to mysterious blockages of later VACUUM commands.
- Prevent failure if client sends Bind protocol message when current transaction is already aborted
- /contrib/tsearch2 and /contrib/ltree fixes (Teodor)
- Fix problems with translated error messages in languages that require word reordering, such as Turkish; also problems with unexpected truncation of output strings and wrong display of the smallest possible bigint value (Andrew, Tom)

  These problems only appeared on platforms that were using our port/snprintf.c code, which includes BSD variants if --enable-nls was given, and perhaps others. In addition, a different form of the translated-error-message problem could appear on Windows depending on which version of libintl was used.

- Re-allow `AM`/`PM`, `HH`, `HH12`, and `D` format specifiers for `to_char(time)` and `to_char(interval)`. (`to_char(interval)` should probably use `HH24`.) (Bruce)
- AIX, HPUX, and MSVC compile fixes (Tom, Hiroshi Saito)
- Optimizer improvements (Tom)
- Retry file reads and writes after Windows NO_SYSTEM_RESOURCES error (Qingqing Zhou)
- Prevent autovacuum from crashing during ANALYZE of expression index (Alvaro)
- Fix problems with ON COMMIT DELETE ROWS temp tables
- Fix problems when a trigger alters the output of a SELECT DISTINCT query
- Add 8.1.0 release note item on how to migrate invalid `UTF-8` byte sequences (Paul Lindner)

E.151. Release 8.1

Release Date: 2005-11-08

E.151.1. Overview

Major changes in this release:

Improve concurrent access to the shared buffer cache (Tom)

Access to the shared buffer cache was identified as a significant scalability problem, particularly on multi-CPU systems. In this release, the way that locking is done in the buffer manager has been overhauled to reduce lock contention and improve scalability. The buffer manager has also been changed to use a "clock sweep" replacement policy.

Allow index scans to use an intermediate in-memory bitmap (Tom)

In previous releases, only a single index could be used to do lookups on a table. With this feature, if a query has `WHERE tab.col1 = 4 and tab.col2 = 9`, and there is no multicolumn index on `col1` and `col2`, but there is an index on `col1` and another on `col2`, it is possible to search both indexes and combine the results in memory, then do heap fetches for only the rows matching both the `col1` and `col2` restrictions. This is very useful in environments that have a lot of unstructured queries where it is impossible to create indexes that match all possible access conditions. Bitmap scans are useful even with a single index, as they reduce the amount of random access needed; a bitmap index scan is efficient for retrieving fairly large fractions of the complete table, whereas plain index scans are not.

Add two-phase commit (Heikki Linnakangas, Alvaro, Tom)

Two-phase commit allows transactions to be "prepared" on several computers, and once all computers have successfully prepared their transactions (none failed), all transactions can be committed. Even if a machine crashes after a prepare, the prepared transaction can be committed after the machine is restarted. New syntax includes `PREPARE TRANSACTION` and `COMMIT/ROLLBACK PREPARED`. A new system view `pg_prepared_xacts` has also been added.

Create a new role system that replaces users and groups (Stephen Frost)

Roles are a combination of users and groups. Like users, they can have login capability, and like groups, a role can have other roles as members. Roles basically remove the distinction between users and groups. For example, a role can:

- Have login capability (optionally)
- Own objects
- Hold access permissions for database objects
- Inherit permissions from other roles it is a member of

Once a user logs into a role, she obtains capabilities of the login role plus any inherited roles, and can use `SET ROLE` to switch to other roles she is a member of. This feature is a generalization of the SQL standard's concept of roles. This change also replaces `pg_shadow` and `pg_group` by new role-capable catalogs `pg_authid` and `pg_auth_members`. The old tables are redefined as read-only views on the new role tables.

Automatically use indexes for `MIN()` and `MAX()` (Tom)

In previous releases, the only way to use an index for `MIN()` or `MAX()` was to rewrite the query as `SELECT col FROM tab ORDER BY col LIMIT 1`. Index usage now happens automatically.

Move `/contrib/pg_autovacuum` into the main server (Alvaro)

Integrating autovacuum into the server allows it to be automatically started and stopped in sync with the database server, and allows autovacuum to be configured from `postgresql.conf`.

Add shared row level locks using `SELECT ... FOR SHARE` (Alvaro)

While PostgreSQL's MVCC locking allows `SELECT` to never be blocked by writers and therefore does not need shared row locks for typical operations, shared locks are useful for applications that require shared row locking. In particular this reduces the locking requirements imposed by referential integrity checks.

Add dependencies on shared objects, specifically roles (Alvaro)

This extension of the dependency mechanism prevents roles from being dropped while there are still database objects they own. Formerly it was possible to accidentally "orphan" objects by deleting their owner. While this could be recovered from, it was messy and unpleasant.

Improve performance for partitioned tables (Simon)

The new `constraint_exclusion` configuration parameter avoids lookups on child tables where constraints indicate that no matching rows exist in the child table.

This allows for a basic type of table partitioning. If child tables store separate key ranges and this is enforced using appropriate `CHECK` constraints, the optimizer will skip child table accesses when the constraint guarantees no matching rows exist in the child table.

E.151.2. Migration to Version 8.1

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

The 8.0 release announced that the `to_char()` function for intervals would be removed in 8.1. However, since no better API has been suggested, `to_char(interval)` has been enhanced in 8.1 and will remain in the server.

Observe the following incompatibilities:

- add_missing_from is now false by default (Neil)

  By default, we now generate an error if a table is used in a query without a FROM reference. The old behavior is still available, but the parameter must be set to 'true' to obtain it.

  It might be necessary to set add_missing_from to true in order to load an existing dump file, if the dump contains any views or rules created using the implicit-FROM syntax. This should be a one-time annoyance, because PostgreSQL 8.1 will convert such views and rules to standard explicit-FROM syntax. Subsequent dumps will therefore not have the problem.

- Cause input of a zero-length string (") for float4/float8/oid to throw an error, rather than treating it as a zero (Neil)

  This change is consistent with the current handling of zero-length strings for integers. The schedule for this change was announced in 8.0.

- default_with_oids is now false by default (Neil)

  With this option set to false, user-created tables no longer have an OID column unless WITH OIDS is specified in CREATE TABLE. Though OIDs have existed in all releases of PostgreSQL, their use is limited because they are only four bytes long and the counter is shared across all installed databases. The preferred way of uniquely identifying rows is via sequences and the SERIAL type, which have been supported since PostgreSQL 6.4.

- Add E" syntax so eventually ordinary strings can treat backslashes literally (Bruce)

  Currently PostgreSQL processes a backslash in a string literal as introducing a special escape sequence, e.g. \n or \010. While this allows easy entry of special values, it is nonstandard and makes porting of applications from other databases more difficult. For this reason, the PostgreSQL project is planning to remove the special meaning of backslashes in strings. For backward compatibility and for users who want special backslash processing, a new string syntax has been created. This new string syntax is formed by writing an E immediately preceding the single quote that starts the string, e.g. E'hi\n'. While this release does not change the handling of backslashes in strings, it does add new configuration parameters to help users migrate applications for future releases:

  - standard_conforming_strings — does this release treat backslashes literally in ordinary strings?
  - escape_string_warning — warn about backslashes in ordinary (non-E) strings

  The standard_conforming_strings value is read-only. Applications can retrieve the value to know how backslashes are processed. (Presence of the parameter can also be taken as an indication that E" string syntax is supported.) In a future release, standard_conforming_strings will be true, meaning backslashes will be treated literally in non-E strings. To prepare for this change, use E" strings in places that need special backslash processing, and turn on escape_string_warning to find additional strings that need to be converted to use E". Also, use two single-quotes (") to embed a literal single-quote in a string, rather than the PostgreSQL-supported syntax of backslash single-quote (\'). The former is standards-conforming and does not require the use of the E" string syntax. You can also use the $$ string syntax, which does not treat backslashes specially.

- Make REINDEX DATABASE reindex all indexes in the database (Tom)

  Formerly, REINDEX DATABASE reindexed only system tables. This new behavior seems more intuitive. A new command REINDEX SYSTEM provides the old functionality of reindexing just the system tables.

- Read-only large object descriptors now obey MVCC snapshot semantics

  When a large object is opened with INV_READ (and not INV_WRITE), the data read from the descriptor will now reflect a "snapshot" of the large object's state at the time of the transaction snap-

shot in use by the query that called `lo_open()`. To obtain the old behavior of always returning the latest committed data, include `INV_WRITE` in the mode flags for `lo_open()`.

- Add proper dependencies for arguments of sequence functions (Tom)

  In previous releases, sequence names passed to `nextval()`, `currval()`, and `setval()` were stored as simple text strings, meaning that renaming or dropping a sequence used in a `DEFAULT` clause made the clause invalid. This release stores all newly-created sequence function arguments as internal OIDs, allowing them to track sequence renaming, and adding dependency information that prevents improper sequence removal. It also makes such `DEFAULT` clauses immune to schema renaming and search path changes.

  Some applications might rely on the old behavior of run-time lookup for sequence names. This can still be done by explicitly casting the argument to `text`, for example `nextval('myseq'::text)`.

  Pre-8.1 database dumps loaded into 8.1 will use the old text-based representation and therefore will not have the features of OID-stored arguments. However, it is possible to update a database containing text-based `DEFAULT` clauses. First, save this query into a file, such as `fixseq.sql`:

```
SELECT  'ALTER TABLE ' ||
   pg_catalog.quote_ident(n.nspname) || '.' ||
   pg_catalog.quote_ident(c.relname) ||
   ' ALTER COLUMN ' || pg_catalog.quote_ident(a.attname) ||
   ' SET DEFAULT ' ||
   regexp_replace(d.adsrc,
                  $$val\(\(('[^']*')::text\)::regclass$$,
                  $$val(\1$$,
                  'g') ||
   ';'
FROM    pg_namespace n, pg_class c, pg_attribute a, pg_attrdef d
WHERE   n.oid = c.relnamespace AND
   c.oid = a.attrelid AND
   a.attrelid = d.adrelid AND
   a.attnum = d.adnum AND
   d.adsrc ~ $$val\(\('[^']*'::text\)::regclass$$;
```

  Next, run the query against a database to find what adjustments are required, like this for database `db1`:

```
psql -t -f fixseq.sql db1
```

  This will show the `ALTER TABLE` commands needed to convert the database to the newer OID-based representation. If the commands look reasonable, run this to update the database:

```
psql -t -f fixseq.sql db1 | psql -e db1
```

  This process must be repeated in each database to be updated.

- In psql, treat unquoted `\{digit}+` sequences as octal (Bruce)

  In previous releases, `\{digit}+` sequences were treated as decimal, and only `\0{digit}+` were treated as octal. This change was made for consistency.

- Remove grammar productions for prefix and postfix `%` and `^` operators (Tom)

  These have never been documented and complicated the use of the modulus operator (`%`) with negative numbers.

- Make `&<` and `&>` for polygons consistent with the box "over" operators (Tom)

- `CREATE LANGUAGE` can ignore the provided arguments in favor of information from `pg_pltemplate` (Tom)

  A new system catalog `pg_pltemplate` has been defined to carry information about the preferred definitions of procedural languages (such as whether they have validator functions). When an en-

try exists in this catalog for the language being created, `CREATE LANGUAGE` will ignore all its parameters except the language name and instead use the catalog information. This measure was taken because of increasing problems with obsolete language definitions being loaded by old dump files. As of 8.1, pg_dump will dump procedural language definitions as just `CREATE LANGUAGE` *`name`*, relying on a template entry to exist at load time. We expect this will be a more future-proof representation.

- Make `pg_cancel_backend(int)` return a `boolean` rather than an `integer` (Neil)
- Some users are having problems loading UTF-8 data into 8.1.X. This is because previous versions allowed invalid UTF-8 byte sequences to be entered into the database, and this release properly accepts only valid UTF-8 sequences. One way to correct a dumpfile is to run the command `iconv -c -f UTF-8 -t UTF-8 -o cleanfile.sql dumpfile.sql`. The `-c` option removes invalid character sequences. A diff of the two files will show the sequences that are invalid. `iconv` reads the entire input file into memory so it might be necessary to use split to break up the dump into multiple smaller files for processing.

E.151.3. Additional Changes

Below you will find a detailed account of the additional changes between PostgreSQL 8.1 and the previous major release.

E.151.3.1. Performance Improvements

- Improve GiST and R-tree index performance (Neil)
- Improve the optimizer, including auto-resizing of hash joins (Tom)
- Overhaul internal API in several areas
- Change WAL record CRCs from 64-bit to 32-bit (Tom)

  We determined that the extra cost of computing 64-bit CRCs was significant, and the gain in reliability too marginal to justify it.
- Prevent writing large empty gaps in WAL pages (Tom)
- Improve spinlock behavior on SMP machines, particularly Opterons (Tom)
- Allow nonconsecutive index columns to be used in a multicolumn index (Tom)

  For example, this allows an index on columns a,b,c to be used in a query with `WHERE a = 4 and c = 10`.
- Skip WAL logging for `CREATE TABLE AS` / `SELECT INTO` (Simon)

  Since a crash during `CREATE TABLE AS` would cause the table to be dropped during recovery, there is no reason to WAL log as the table is loaded. (Logging still happens if WAL archiving is enabled, however.)
- Allow concurrent GiST index access (Teodor, Oleg)
- Add configuration parameter `full_page_writes` to control writing full pages to WAL (Bruce)

  To prevent partial disk writes from corrupting the database, PostgreSQL writes a complete copy of each database disk page to WAL the first time it is modified after a checkpoint. This option turns off that functionality for more speed. This is safe to use with battery-backed disk caches where partial page writes cannot happen.

- Use `O_DIRECT` if available when using `O_SYNC` for `wal_sync_method` (Itagaki Takahiro)

  `O_DIRECT` causes disk writes to bypass the kernel cache, and for WAL writes, this improves performance.

- Improve `COPY FROM` performance (Alon Goldshuv)

  This was accomplished by reading `COPY` input in larger chunks, rather than character by character.

- Improve the performance of `COUNT()`, `SUM`, `AVG()`, `STDDEV()`, and `VARIANCE()` (Neil, Tom)

E.151.3.2. Server Changes

- Prevent problems due to transaction ID (XID) wraparound (Tom)

  The server will now warn when the transaction counter approaches the wraparound point. If the counter becomes too close to wraparound, the server will stop accepting queries. This ensures that data is not lost before needed vacuuming is performed.

- Fix problems with object IDs (OIDs) conflicting with existing system objects after the OID counter has wrapped around (Tom)

- Add warning about the need to increase `max_fsm_relations` and `max_fsm_pages` during `VACUUM` (Ron Mayer)

- Add `temp_buffers` configuration parameter to allow users to determine the size of the local buffer area for temporary table access (Tom)

- Add session start time and client IP address to `pg_stat_activity` (Magnus)

- Adjust `pg_stat` views for bitmap scans (Tom)

  The meanings of some of the fields have changed slightly.

- Enhance `pg_locks` view (Tom)

- Log queries for client-side `PREPARE` and `EXECUTE` (Simon)

- Allow Kerberos name and user name case sensitivity to be specified in `postgresql.conf` (Magnus)

- Add configuration parameter `krb_server_hostname` so that the server host name can be specified as part of service principal (Todd Kover)

  If not set, any service principal matching an entry in the keytab can be used. This is new Kerberos matching behavior in this release.

- Add `log_line_prefix` options for millisecond timestamps (`%m`) and remote host (`%h`) (Ed L.)

- Add WAL logging for GiST indexes (Teodor, Oleg)

  GiST indexes are now safe for crash and point-in-time recovery.

- Remove old `*.backup` files when we do `pg_stop_backup()` (Bruce)

  This prevents a large number of `*.backup` files from existing in `pg_xlog/`.

- Add configuration parameters to control TCP/IP keep-alive times for idle, interval, and count (Oliver Jowett)

  These values can be changed to allow more rapid detection of lost client connections.

- Add per-user and per-database connection limits (Petr Jelinek)

Using `ALTER USER` and `ALTER DATABASE`, limits can now be enforced on the maximum number of sessions that can concurrently connect as a specific user or to a specific database. Setting the limit to zero disables user or database connections.

- Allow more than two gigabytes of shared memory and per-backend work memory on 64-bit machines (Koichi Suzuki)
- New system catalog `pg_pltemplate` allows overriding obsolete procedural-language definitions in dump files (Tom)

E.151.3.3. Query Changes

- Add temporary views (Koju Iijima, Neil)
- Fix `HAVING` without any aggregate functions or `GROUP BY` so that the query returns a single group (Tom)

  Previously, such a case would treat the `HAVING` clause the same as a `WHERE` clause. This was not per spec.
- Add `USING` clause to allow additional tables to be specified to `DELETE` (Euler Taveira de Oliveira, Neil)

  In prior releases, there was no clear method for specifying additional tables to be used for joins in a `DELETE` statement. `UPDATE` already has a `FROM` clause for this purpose.
- Add support for `\x` hex escapes in backend and ecpg strings (Bruce)

  This is just like the standard C `\x` escape syntax. Octal escapes were already supported.
- Add `BETWEEN SYMMETRIC` query syntax (Pavel Stehule)

  This feature allows `BETWEEN` comparisons without requiring the first value to be less than the second. For example, `2 BETWEEN [ASYMMETRIC] 3 AND 1` returns false, while `2 BETWEEN SYMMETRIC 3 AND 1` returns true. `BETWEEN ASYMMETRIC` was already supported.
- Add `NOWAIT` option to `SELECT ... FOR UPDATE/SHARE` (Hans-Juergen Schoenig)

  While the `statement_timeout` configuration parameter allows a query taking more than a certain amount of time to be canceled, the `NOWAIT` option allows a query to be canceled as soon as a `SELECT ... FOR UPDATE/SHARE` command cannot immediately acquire a row lock.

E.151.3.4. Object Manipulation Changes

- Track dependencies of shared objects (Alvaro)

  PostgreSQL allows global tables (users, databases, tablespaces) to reference information in multiple databases. This addition adds dependency information for global tables, so, for example, user ownership can be tracked across databases, so a user who owns something in any database can no longer be removed. Dependency tracking already existed for database-local objects.
- Allow limited `ALTER OWNER` commands to be performed by the object owner (Stephen Frost)

  Prior releases allowed only superusers to change object owners. Now, ownership can be transferred if the user executing the command owns the object and would be able to create it as the new owner (that is, the user is a member of the new owning role and that role has the CREATE permission that would be needed to create the object afresh).

- Add `ALTER` object `SET SCHEMA` capability for some object types (tables, functions, types) (Bernd Helmle)

  This allows objects to be moved to different schemas.

- Add `ALTER TABLE ENABLE/DISABLE TRIGGER` to disable triggers (Satoshi Nagayasu)

E.151.3.5. Utility Command Changes

- Allow `TRUNCATE` to truncate multiple tables in a single command (Alvaro)

  Because of referential integrity checks, it is not allowed to truncate a table that is part of a referential integrity constraint. Using this new functionality, `TRUNCATE` can be used to truncate such tables, if both tables involved in a referential integrity constraint are truncated in a single `TRUNCATE` command.

- Properly process carriage returns and line feeds in `COPY CSV` mode (Andrew)

  In release 8.0, carriage returns and line feeds in `CSV COPY TO` were processed in an inconsistent manner. (This was documented on the TODO list.)

- Add `COPY WITH CSV HEADER` to allow a header line as the first line in `COPY` (Andrew)

  This allows handling of the common `CSV` usage of placing the column names on the first line of the data file. For `COPY TO`, the first line contains the column names, and for `COPY FROM`, the first line is ignored.

- On Windows, display better sub-second precision in `EXPLAIN ANALYZE` (Magnus)

- Add trigger duration display to `EXPLAIN ANALYZE` (Tom)

  Prior releases included trigger execution time as part of the total execution time, but did not show it separately. It is now possible to see how much time is spent in each trigger.

- Add support for `\x` hex escapes in `COPY` (Sergey Ten)

  Previous releases only supported octal escapes.

- Make `SHOW ALL` include variable descriptions (Matthias Schmidt)

  `SHOW` varname still only displays the variable's value and does not include the description.

- Make initdb create a new standard database called `postgres`, and convert utilities to use `postgres` rather than `template1` for standard lookups (Dave)

  In prior releases, `template1` was used both as a default connection for utilities like createuser, and as a template for new databases. This caused `CREATE DATABASE` to sometimes fail, because a new database cannot be created if anyone else is in the template database. With this change, the default connection database is now `postgres`, meaning it is much less likely someone will be using `template1` during `CREATE DATABASE`.

- Create new reindexdb command-line utility by moving `/contrib/reindexdb` into the server (Euler Taveira de Oliveira)

E.151.3.6. Data Type and Function Changes

- Add `MAX()` and `MIN()` aggregates for array types (Koju Iijima)

- Fix `to_date()` and `to_timestamp()` to behave reasonably when `CC` and `YY` fields are both used (Karel Zak)

If the format specification contains `CC` and a year specification is `YYY` or longer, ignore the `CC`. If the year specification is `YY` or shorter, interpret `CC` as the previous century.

- Add `md5(bytea)` (Abhijit Menon-Sen)

  `md5(text)` already existed.

- Add support for `numeric ^ numeric` based on `power(numeric, numeric)`

  The function already existed, but there was no operator assigned to it.

- Fix `NUMERIC` modulus by properly truncating the quotient during computation (Bruce)

  In previous releases, modulus for large values sometimes returned negative results due to rounding of the quotient.

- Add a function `lastval()` (Dennis Björklund)

  `lastval()` is a simplified version of `currval()`. It automatically determines the proper sequence name based on the most recent `nextval()` or `setval()` call performed by the current session.

- Add `to_timestamp(DOUBLE PRECISION)` (Michael Glaesemann)

  Converts Unix seconds since 1970 to a `TIMESTAMP WITH TIMEZONE`.

- Add `pg_postmaster_start_time()` function (Euler Taveira de Oliveira, Matthias Schmidt)

- Allow the full use of time zone names in `AT TIME ZONE`, not just the short list previously available (Magnus)

  Previously, only a predefined list of time zone names were supported by `AT TIME ZONE`. Now any supported time zone name can be used, e.g.:

  ```
  SELECT CURRENT_TIMESTAMP AT TIME ZONE 'Europe/London';
  ```

  In the above query, the time zone used is adjusted based on the daylight saving time rules that were in effect on the supplied date.

- Add `GREATEST()` and `LEAST()` variadic functions (Pavel Stehule)

  These functions take a variable number of arguments and return the greatest or least value among the arguments.

- Add `pg_column_size()` (Mark Kirkwood)

  This returns storage size of a column, which might be compressed.

- Add `regexp_replace()` (Atsushi Ogawa)

  This allows regular expression replacement, like sed. An optional flag argument allows selection of global (replace all) and case-insensitive modes.

- Fix interval division and multiplication (Bruce)

  Previous versions sometimes returned unjustified results, like `'4 months'::interval / 5` returning `'1 mon -6 days'`.

- Fix roundoff behavior in timestamp, time, and interval output (Tom)

  This fixes some cases in which the seconds field would be shown as `60` instead of incrementing the higher-order fields.

- Add a separate day field to type `interval` so a one day interval can be distinguished from a 24 hour interval (Michael Glaesemann)

  Days that contain a daylight saving time adjustment are not 24 hours long, but typically 23 or 25 hours. This change creates a conceptual distinction between intervals of "so many days" and intervals of "so many hours". Adding `1 day` to a timestamp now gives the same local time on the

next day even if a daylight saving time adjustment occurs between, whereas adding `24 hours` will give a different local time when this happens. For example, under US DST rules:

```
'2005-04-03 00:00:00-05' + '1 day' = '2005-04-04 00:00:00-04'
'2005-04-03 00:00:00-05' + '24 hours' = '2005-04-04 01:00:00-04'
```

- Add `justify_days()` and `justify_hours()` (Michael Glaesemann)

  These functions, respectively, adjust days to an appropriate number of full months and days, and adjust hours to an appropriate number of full days and hours.

- Move `/contrib/dbsize` into the backend, and rename some of the functions (Dave Page, Andreas Pflug)

  - `pg_tablespace_size()`
  - `pg_database_size()`
  - `pg_relation_size()`
  - `pg_total_relation_size()`
  - `pg_size_pretty()`

  `pg_total_relation_size()` includes indexes and TOAST tables.

- Add functions for read-only file access to the cluster directory (Dave Page, Andreas Pflug)

  - `pg_stat_file()`
  - `pg_read_file()`
  - `pg_ls_dir()`

- Add `pg_reload_conf()` to force reloading of the configuration files (Dave Page, Andreas Pflug)
- Add `pg_rotate_logfile()` to force rotation of the server log file (Dave Page, Andreas Pflug)
- Change `pg_stat_*` views to include TOAST tables (Tom)

E.151.3.7. Encoding and Locale Changes

- Rename some encodings to be more consistent and to follow international standards (Bruce)

  - `UNICODE` is now `UTF8`
  - `ALT` is now `WIN866`
  - `WIN` is now `WIN1251`
  - `TCVN` is now `WIN1258`

  The original names still work.

- Add support for `WIN1252` encoding (Roland Volkmann)
- Add support for four-byte `UTF8` characters (John Hansen)

  Previously only one, two, and three-byte `UTF8` characters were supported. This is particularly important for support for some Chinese character sets.

- Allow direct conversion between `EUC_JP` and `SJIS` to improve performance (Atsushi Ogawa)
- Allow the UTF8 encoding to work on Windows (Magnus)

  This is done by mapping UTF8 to the Windows-native UTF16 implementation.

E.151.3.8. General Server-Side Language Changes

- Fix `ALTER LANGUAGE RENAME` (Sergey Yatskevich)
- Allow function characteristics, like strictness and volatility, to be modified via `ALTER FUNCTION` (Neil)
- Increase the maximum number of function arguments to 100 (Tom)
- Allow SQL and PL/pgSQL functions to use `OUT` and `INOUT` parameters (Tom)

  `OUT` is an alternate way for a function to return values. Instead of using `RETURN`, values can be returned by assigning to parameters declared as `OUT` or `INOUT`. This is notationally simpler in some cases, particularly so when multiple values need to be returned. While returning multiple values from a function was possible in previous releases, this greatly simplifies the process. (The feature will be extended to other server-side languages in future releases.)
- Move language handler functions into the `pg_catalog` schema

  This makes it easier to drop the public schema if desired.
- Add `SPI_getnspname()` to SPI (Neil)

E.151.3.9. PL/pgSQL Server-Side Language Changes

- Overhaul the memory management of PL/pgSQL functions (Neil)

  The parsetree of each function is now stored in a separate memory context. This allows this memory to be easily reclaimed when it is no longer needed.
- Check function syntax at `CREATE FUNCTION` time, rather than at runtime (Neil)

  Previously, most syntax errors were reported only when the function was executed.
- Allow `OPEN` to open non-`SELECT` queries like `EXPLAIN` and `SHOW` (Tom)
- No longer require functions to issue a `RETURN` statement (Tom)

  This is a byproduct of the newly added `OUT` and `INOUT` functionality. `RETURN` can be omitted when it is not needed to provide the function's return value.
- Add support for an optional `INTO` clause to PL/pgSQL's `EXECUTE` statement (Pavel Stehule, Neil)
- Make `CREATE TABLE AS` set `ROW_COUNT` (Tom)
- Define `SQLSTATE` and `SQLERRM` to return the `SQLSTATE` and error message of the current exception (Pavel Stehule, Neil)

  These variables are only defined inside exception blocks.
- Allow the parameters to the `RAISE` statement to be expressions (Pavel Stehule, Neil)
- Add a loop `CONTINUE` statement (Pavel Stehule, Neil)
- Allow block and loop labels (Pavel Stehule)

E.151.3.10. PL/Perl Server-Side Language Changes

- Allow large result sets to be returned efficiently (Abhijit Menon-Sen)

  This allows functions to use `return_next()` to avoid building the entire result set in memory.

- Allow one-row-at-a-time retrieval of query results (Abhijit Menon-Sen)

  This allows functions to use `spi_query()` and `spi_fetchrow()` to avoid accumulating the entire result set in memory.

- Force PL/Perl to handle strings as `UTF8` if the server encoding is `UTF8` (David Kamholz)

- Add a validator function for PL/Perl (Andrew)

  This allows syntax errors to be reported at definition time, rather than execution time.

- Allow PL/Perl to return a Perl array when the function returns an array type (Andrew)

  This basically maps PostgreSQL arrays to Perl arrays.

- Allow Perl nonfatal warnings to generate `NOTICE` messages (Andrew)

- Allow Perl's `strict` mode to be enabled (Andrew)

E.151.3.11. psql Changes

- Add `\set ON_ERROR_ROLLBACK` to allow statements in a transaction to error without affecting the rest of the transaction (Greg Sabino Mullane)

  This is basically implemented by wrapping every statement in a sub-transaction.

- Add support for `\x` hex strings in psql variables (Bruce)

  Octal escapes were already supported.

- Add support for `troff -ms` output format (Roger Leigh)

- Allow the history file location to be controlled by `HISTFILE` (Andreas Seltenreich)

  This allows configuration of per-database history storage.

- Prevent `\x` (expanded mode) from affecting the output of `\d tablename` (Neil)

- Add `-L` option to psql to log sessions (Lorne Sunley)

  This option was added because some operating systems do not have simple command-line activity logging functionality.

- Make `\d` show the tablespaces of indexes (Qingqing Zhou)

- Allow psql help (`\h`) to make a best guess on the proper help information (Greg Sabino Mullane)

  This allows the user to just add `\h` to the front of the syntax error query and get help on the supported syntax. Previously any additional query text beyond the command name had to be removed to use `\h`.

- Add `\pset numericlocale` to allow numbers to be output in a locale-aware format (Eugen Nedelcu)

  For example, using `C` locale `100000` would be output as `100,000.0` while a European locale might output this value as `100.000,0`.

- Make startup banner show both server version number and psql's version number, when they are different (Bruce)

Also, a warning will be shown if the server and psql are from different major releases.

E.151.3.12. pg_dump Changes

- Add `-n` / `--schema` switch to pg_restore (Richard van den Berg)

  This allows just the objects in a specified schema to be restored.
- Allow pg_dump to dump large objects even in text mode (Tom)

  With this change, large objects are now always dumped; the former `-b` switch is a no-op.
- Allow pg_dump to dump a consistent snapshot of large objects (Tom)
- Dump comments for large objects (Tom)
- Add `--encoding` to pg_dump (Magnus Hagander)

  This allows a database to be dumped in an encoding that is different from the server's encoding. This is valuable when transferring the dump to a machine with a different encoding.
- Rely on `pg_pltemplate` for procedural languages (Tom)

  If the call handler for a procedural language is in the `pg_catalog` schema, pg_dump does not dump the handler. Instead, it dumps the language using just `CREATE LANGUAGE` *`name`*, relying on the `pg_pltemplate` catalog to provide the language's creation parameters at load time.

E.151.3.13. libpq Changes

- Add a `PGPASSFILE` environment variable to specify the password file's filename (Andrew)
- Add `lo_create()`, that is similar to `lo_creat()` but allows the OID of the large object to be specified (Tom)
- Make libpq consistently return an error to the client application on `malloc()` failure (Neil)

E.151.3.14. Source Code Changes

- Fix pgxs to support building against a relocated installation
- Add spinlock support for the Itanium processor using Intel compiler (Vikram Kalsi)
- Add Kerberos 5 support for Windows (Magnus)
- Add Chinese FAQ (laser@pgsqldb.com)
- Rename Rendezvous to Bonjour to match OS/X feature renaming (Bruce)
- Add support for `fsync_writethrough` on Darwin (Chris Campbell)
- Streamline the passing of information within the server, the optimizer, and the lock system (Tom)
- Allow pg_config to be compiled using MSVC (Andrew)

  This is required to build DBD::Pg using MSVC.
- Remove support for Kerberos V4 (Magnus)

  Kerberos 4 had security vulnerabilities and is no longer maintained.
- Code cleanups (Coverity static analysis performed by EnterpriseDB)

- Modify `postgresql.conf` to use documentation defaults `on`/`off` rather than `true`/`false` (Bruce)
- Enhance pg_config to be able to report more build-time values (Tom)
- Allow libpq to be built thread-safe on Windows (Dave Page)
- Allow IPv6 connections to be used on Windows (Andrew)
- Add Server Administration documentation about I/O subsystem reliability (Bruce)
- Move private declarations from `gist.h` to `gist_private.h` (Neil)

  In previous releases, `gist.h` contained both the public GiST API (intended for use by authors of GiST index implementations) as well as some private declarations used by the implementation of GiST itself. The latter have been moved to a separate file, `gist_private.h`. Most GiST index implementations should be unaffected.
- Overhaul GiST memory management (Neil)

  GiST methods are now always invoked in a short-lived memory context. Therefore, memory allocated via `palloc()` will be reclaimed automatically, so GiST index implementations do not need to manually release allocated memory via `pfree()`.

E.151.3.15. Contrib Changes

- Add `/contrib/pg_buffercache` contrib module (Mark Kirkwood)

  This displays the contents of the buffer cache, for debugging and performance tuning purposes.
- Remove `/contrib/array` because it is obsolete (Tom)
- Clean up the `/contrib/lo` module (Tom)
- Move `/contrib/findoidjoins` to `/src/tools` (Tom)
- Remove the <<, >>, &<, and &> operators from `/contrib/cube`

  These operators were not useful.
- Improve `/contrib/btree_gist` (Janko Richter)
- Improve `/contrib/pgbench` (Tomoaki Sato, Tatsuo)

  There is now a facility for testing with SQL command scripts given by the user, instead of only a hard-wired command sequence.
- Improve `/contrib/pgcrypto` (Marko Kreen)
  - Implementation of OpenPGP symmetric-key and public-key encryption

    Both RSA and Elgamal public-key algorithms are supported.
  - Stand alone build: include SHA256/384/512 hashes, Fortuna PRNG
  - OpenSSL build: support 3DES, use internal AES with OpenSSL < 0.9.7
  - Take build parameters (OpenSSL, zlib) from `configure` result

    There is no need to edit the `Makefile` anymore.
  - Remove support for `libmhash` and `libmcrypt`

E.152. Release 8.0.26

Release Date: 2010-10-04

This release contains a variety of fixes from 8.0.25. For information about new features in the 8.0 major release, see Section E.178.

This is expected to be the last PostgreSQL release in the 8.0.X series. Users are encouraged to update to a newer release branch soon.

E.152.1. Migration to Version 8.0.26

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.22, see Section E.156.

E.152.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

  It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

  Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)

- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.

- Defend against functions returning setof record where not all the returned rows are actually of the same rowtype (Tom Lane)

- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.

- Avoid recursion while assigning XIDs to heavily-nested subtransactions (Andres Freund, Robert Haas)

  The original coding could result in a crash if there was limited stack space.

- Fix `log_line_prefix`'s `%i` escape, which could produce junk early in backend startup (Tom Lane)
- Fix possible data corruption in `ALTER TABLE ... SET TABLESPACE` when archiving is enabled (Jeff Davis)
- Allow `CREATE DATABASE` and `ALTER DATABASE ... SET TABLESPACE` to be interrupted by query-cancel (Guillaume Lelarge)
- In PL/Python, defend against null pointer results from `PyCObject_AsVoidPtr` and `PyCObject_FromVoidPtr` (Peter Eisentraut)
- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)
- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)
- Fix `contrib/dblink` to handle connection names longer than 62 bytes correctly (Itagaki Takahiro)
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)
- Update time zone data files to tzdata release 2010l for DST law changes in Egypt and Palestine; also historical corrections for Finland.

  This change also adds new names for two Micronesian timezones: Pacific/Chuuk is now preferred over Pacific/Truk (and the preferred abbreviation is CHUT not TRUT) and Pacific/Pohnpei is preferred over Pacific/Ponape.

E.153. Release 8.0.25

Release Date: 2010-05-17

This release contains a variety of fixes from 8.0.24. For information about new features in the 8.0 major release, see Section E.178.

The PostgreSQL community will stop releasing updates for the 8.0.X release series in July 2010. Users are encouraged to update to a newer release branch soon.

E.153.1. Migration to Version 8.0.25

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.22, see Section E.156.

E.153.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b` variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

  Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

  In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)

- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)

- Prevent infinite recursion in psql when expanding a variable that refers to itself (Tom)

- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)

- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.

- Update time zone data files to tzdata release 2010j for DST law changes in Argentina, Australian Antarctic, Bangladesh, Mexico, Morocco, Pakistan, Palestine, Russia, Syria, Tunisia; also historical corrections for Taiwan.

E.154. Release 8.0.24

Release Date: 2010-03-15

This release contains a variety of fixes from 8.0.23. For information about new features in the 8.0 major release, see Section E.178.

The PostgreSQL community will stop releasing updates for the 8.0.X release series in July 2010. Users are encouraged to update to a newer release branch soon.

E.154.1. Migration to Version 8.0.24

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.22, see Section E.156.

E.154.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.

- Fix possible crashes when trying to recover from a failure in subtransaction start (Tom)

- Fix server memory leak associated with use of savepoints and a client encoding different from server's encoding (Tom)

- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).

- Fix integer-to-bit-string conversions to handle the first fractional byte correctly when the output bit width is wider than the given integer by something other than a multiple of 8 bits (Tom)

- Fix some cases of pathologically slow regular expression matching (Tom)

- Fix the `STOP WAL LOCATION` entry in backup history files to report the next WAL segment's name when the end location is exactly at a segment boundary (Itagaki Takahiro)

- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.

- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)

- Fix plpgsql failure in one case where a composite column is set to NULL (Tom)

- Add `volatile` markings in PL/Python to avoid possible compiler-specific misbehavior (Zdenek Kotala)

- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.

- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)
- Fix assorted crashes in `contrib/xml2` caused by sloppy memory management (Tom)
- Update time zone data files to tzdata release 2010e for DST law changes in Bangladesh, Chile, Fiji, Mexico, Paraguay, Samoa.

E.155. Release 8.0.23

Release Date: 2009-12-14

This release contains a variety of fixes from 8.0.22. For information about new features in the 8.0 major release, see Section E.178.

E.155.1. Migration to Version 8.0.23

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.22, see Section E.156.

E.155.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).
- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).
- Fix possible crash during backend-startup-time cache initialization (Tom)
- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.
- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.
- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)
- Fix premature drop of temporary files used for a cursor that is accessed within a subtransaction (Heikki)

- Fix PAM password processing to be more robust (Tom)

  The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.

- Fix rare crash in exception processing in PL/Python (Peter)

- Ensure psql's flex module is compiled with the correct system header definitions (Tom)

  This fixes build failures on platforms where `--enable-largefile` causes incompatible changes in the generated code.

- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)

- Update time zone data files to tzdata release 2009s for DST law changes in Antarctica, Argentina, Bangladesh, Fiji, Novokuznetsk, Pakistan, Palestine, Samoa, Syria; also historical corrections for Hong Kong.

E.156. Release 8.0.22

Release Date: 2009-09-09

This release contains a variety of fixes from 8.0.21. For information about new features in the 8.0 major release, see Section E.178.

E.156.1. Migration to Version 8.0.22

A dump/restore is not required for those running 8.0.X. However, if you have any hash indexes on `interval` columns, you must `REINDEX` them after updating to 8.0.22. Also, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.156.2. Changes

- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

  This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)

- Fix handling of sub-SELECTs appearing in the arguments of an outer-level aggregate function (Tom)

- Fix hash calculation for data type `interval` (Tom)

  This corrects wrong results for hash joins on interval values. It also changes the contents of hash indexes on interval columns. If you have any such indexes, you must `REINDEX` them after updating.

- Treat `to_char(..., 'TH')` as an uppercase ordinal suffix with `'HH'`/`'HH12'` (Heikki)

  It was previously handled as `'th'` (lowercase).

- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Fix calculation of distance between a point and a line segment (Tom)

  This led to incorrect results from a number of geometric operators.
- Fix `money` data type to work in locales where currency amounts have no fractional digits, e.g. Japan (Itagaki Takahiro)
- Properly round datetime input like `00:12:57.9999999999999999999999999999` (Tom)
- Fix poor choice of page split point in GiST R-tree operator classes (Teodor)
- Fix portability issues in plperl initialization (Andrew Dunstan)
- Fix pg_ctl to not go into an infinite loop if `postgresql.conf` is empty (Jeff Davis)
- Fix `contrib/xml2`'s `xslt_process()` to properly handle the maximum number of parameters (twenty) (Tom)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)
- Update time zone data files to tzdata release 2009l for DST law changes in Bangladesh, Egypt, Jordan, Pakistan, Argentina/San_Luis, Cuba, Jordan (historical correction only), Mauritius, Morocco, Palestine, Syria, Tunisia.

E.157. Release 8.0.21

Release Date: 2009-03-16

This release contains a variety of fixes from 8.0.20. For information about new features in the 8.0 major release, see Section E.178.

E.157.1. Migration to Version 8.0.21

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.157.2. Changes

- Prevent error recursion crashes when encoding conversion fails (Tom)

  This change extends fixes made in the last two minor releases for related failure scenarios. The previous fixes were narrowly tailored for the original problem reports, but we have now recognized that *any* error thrown by an encoding conversion function could potentially lead to infinite recursion while trying to report the error. The solution therefore is to disable translation and encoding conversion and report the plain-ASCII form of any error message, if we find we have gotten into a recursive error reporting situation. (CVE-2009-0922)

- Disallow `CREATE CONVERSION` with the wrong encodings for the specified conversion function (Heikki)

  This prevents one possible scenario for encoding conversion failure. The previous change is a backstop to guard against other kinds of failures in the same area.
- Fix core dump when `to_char()` is given format codes that are inappropriate for the type of the data argument (Tom)
- Add `MUST` (Mauritius Island Summer Time) to the default list of known timezone abbreviations (Xavier Bugaud)

E.158. Release 8.0.20

Release Date: 2009-02-02

This release contains a variety of fixes from 8.0.19. For information about new features in the 8.0 major release, see Section E.178.

E.158.1. Migration to Version 8.0.20

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.158.2. Changes

- Improve handling of URLs in `headline()` function (Teodor)
- Improve handling of overlength headlines in `headline()` function (Teodor)
- Prevent possible Assert failure or misconversion if an encoding conversion is created with the wrong conversion function for the specified pair of encodings (Tom, Heikki)
- Avoid unnecessary locking of small tables in `VACUUM` (Heikki)
- Fix uninitialized variables in `contrib/tsearch2`'s `get_covers()` function (Teodor)
- Make all documentation reference `pgsql-bugs` and/or `pgsql-hackers` as appropriate, instead of the now-decommissioned `pgsql-ports` and `pgsql-patches` mailing lists (Tom)
- Update time zone data files to tzdata release 2009a (for Kathmandu and historical DST corrections in Switzerland, Cuba)

E.159. Release 8.0.19

Release Date: 2008-11-03

This release contains a variety of fixes from 8.0.18. For information about new features in the 8.0 major release, see Section E.178.

E.159.1. Migration to Version 8.0.19

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.159.2. Changes

- Fix backend crash when the client encoding cannot represent a localized error message (Tom)

  We have addressed similar issues before, but it would still fail if the "character has no equivalent" message itself couldn't be converted. The fix is to disable localization and send the plain ASCII error message when we detect such a situation.
- Fix possible crash when deeply nested functions are invoked from a trigger (Tom)
- Ensure an error is reported when a newly-defined PL/pgSQL trigger function is invoked as a normal function (Tom)
- Fix incorrect tsearch2 headline generation when single query item matches first word of text (Sushant Sinha)
- Fix improper display of fractional seconds in interval values when using a non-ISO datestyle in an `--enable-integer-datetimes` build (Ron Mayer)
- Ensure `SPI_getvalue` and `SPI_getbinval` behave correctly when the passed tuple and tuple descriptor have different numbers of columns (Tom)

  This situation is normal when a table has had columns added or removed, but these two functions didn't handle it properly. The only likely consequence is an incorrect error indication.
- Fix ecpg's parsing of `CREATE USER` (Michael)
- Fix recent breakage of `pg_ctl restart` (Tom)
- Update time zone data files to tzdata release 2008i (for DST law changes in Argentina, Brazil, Mauritius, Syria)

E.160. Release 8.0.18

Release Date: 2008-09-22

This release contains a variety of fixes from 8.0.17. For information about new features in the 8.0 major release, see Section E.178.

E.160.1. Migration to Version 8.0.18

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.160.2. Changes

- Widen local lock counters from 32 to 64 bits (Tom)

  This responds to reports that the counters could overflow in sufficiently long transactions, leading to unexpected "lock is already held" errors.

- Add checks in executor startup to ensure that the tuples produced by an `INSERT` or `UPDATE` will match the target table's current rowtype (Tom)

  `ALTER COLUMN TYPE`, followed by re-use of a previously cached plan, could produce this type of situation. The check protects against data corruption and/or crashes that could ensue.

- Fix datetime input functions to correctly detect integer overflow when running on a 64-bit platform (Tom)

- Improve performance of writing very long log messages to syslog (Tom)

- Fix bug in backwards scanning of a cursor on a `SELECT DISTINCT ON` query (Tom)

- Fix planner to estimate that `GROUP BY` expressions yielding boolean results always result in two groups, regardless of the expressions' contents (Tom)

  This is very substantially more accurate than the regular `GROUP BY` estimate for certain boolean tests like *`col`* `IS NULL`.

- Fix PL/Tcl to behave correctly with Tcl 8.5, and to be more careful about the encoding of data sent to or from Tcl (Tom)

- Fix PL/Python to work with Python 2.5

  This is a back-port of fixes made during the 8.2 development cycle.

- Improve pg_dump and pg_restore's error reporting after failure to send a SQL command (Tom)

- Fix pg_ctl to properly preserve postmaster command-line arguments across a `restart` (Bruce)

- Update time zone data files to tzdata release 2008f (for DST law changes in Argentina, Bahamas, Brazil, Mauritius, Morocco, Pakistan, Palestine, and Paraguay)

E.161. Release 8.0.17

Release Date: 2008-06-12

This release contains one serious bug fix over 8.0.16. For information about new features in the 8.0 major release, see Section E.178.

E.161.1. Migration to Version 8.0.17

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.161.2. Changes

- Make `pg_get_ruledef()` parenthesize negative constants (Tom)

  Before this fix, a negative constant in a view or rule might be dumped as, say, `-42::integer`, which is subtly incorrect: it should be `(-42)::integer` due to operator precedence rules. Usually this would make little difference, but it could interact with another recent patch to cause PostgreSQL to reject what had been a valid `SELECT DISTINCT` view query. Since this could result in pg_dump output failing to reload, it is being treated as a high-priority fix. The only released versions in which dump output is actually incorrect are 8.3.1 and 8.2.7.

E.162. Release 8.0.16

Release Date: never released

This release contains a variety of fixes from 8.0.15. For information about new features in the 8.0 major release, see Section E.178.

E.162.1. Migration to Version 8.0.16

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.162.2. Changes

- Fix `ALTER TABLE ADD COLUMN ... PRIMARY KEY` so that the new column is correctly checked to see if it's been initialized to all non-nulls (Brendan Jurd)

  Previous versions neglected to check this requirement at all.

- Fix possible `CREATE TABLE` failure when inheriting the "same" constraint from multiple parent relations that inherited that constraint from a common ancestor (Tom)

- Fix conversions between ISO-8859-5 and other encodings to handle Cyrillic "Yo" characters (`ё` and `Ё` with two dots) (Sergey Burladyan)

- Fix a few datatype input functions that were allowing unused bytes in their results to contain uninitialized, unpredictable values (Tom)

  This could lead to failures in which two apparently identical literal values were not seen as equal, resulting in the parser complaining about unmatched `ORDER BY` and `DISTINCT` expressions.

- Fix a corner case in regular-expression substring matching (`substring(`*`string`* `from` *`pattern`*`)`) (Tom)

  The problem occurs when there is a match to the pattern overall but the user has specified a parenthesized subexpression and that subexpression hasn't got a match. An example is `substring('foo' from 'foo(bar)?')`. This should return NULL, since `(bar)` isn't matched, but it was mistakenly returning the whole-pattern match instead (ie, `foo`).

- Update time zone data files to tzdata release 2008c (for DST law changes in Morocco, Iraq, Choibalsan, Pakistan, Syria, Cuba, Argentina/San_Luis, and Chile)

- Fix incorrect result from ecpg's `PGTYPEStimestamp_sub()` function (Michael)

- Fix core dump in `contrib/xml2`'s `xpath_table()` function when the input query returns a NULL value (Tom)

- Fix `contrib/xml2`'s makefile to not override `CFLAGS` (Tom)

- Fix `DatumGetBool` macro to not fail with gcc 4.3 (Tom)

  This problem affects "old style" (V0) C functions that return boolean. The fix is already in 8.3, but the need to back-patch it was not realized at the time.

- Fix longstanding `LISTEN`/`NOTIFY` race condition (Tom)

  In rare cases a session that had just executed a `LISTEN` might not get a notification, even though one would be expected because the concurrent transaction executing `NOTIFY` was observed to commit later.

  A side effect of the fix is that a transaction that has executed a not-yet-committed `LISTEN` command will not see any row in `pg_listener` for the `LISTEN`, should it choose to look; formerly it would have. This behavior was never documented one way or the other, but it is possible that some applications depend on the old behavior.

- Fix rare crash when an error occurs during a query using a hash index (Heikki)

- Fix input of datetime values for February 29 in years BC (Tom)

  The former coding was mistaken about which years were leap years.

- Fix "unrecognized node type" error in some variants of `ALTER OWNER` (Tom)

- Fix pg_ctl to correctly extract the postmaster's port number from command-line options (Itagaki Takahiro, Tom)

  Previously, `pg_ctl start -w` could try to contact the postmaster on the wrong port, leading to bogus reports of startup failure.

- Use `-fwrapv` to defend against possible misoptimization in recent gcc versions (Tom)

  This is known to be necessary when building PostgreSQL with gcc 4.3 or later.

- Fix display of constant expressions in `ORDER BY` and `GROUP BY` (Tom)

  An explicitly casted constant would be shown incorrectly. This could for example lead to corruption of a view definition during dump and reload.

- Fix libpq to handle NOTICE messages correctly during COPY OUT (Tom)

  This failure has only been observed to occur when a user-defined datatype's output routine issues a NOTICE, but there is no guarantee it couldn't happen due to other causes.

E.163. Release 8.0.15

Release Date: 2008-01-07

This release contains a variety of fixes from 8.0.14, including fixes for significant security issues. For information about new features in the 8.0 major release, see Section E.178.

This is the last 8.0.X release for which the PostgreSQL community will produce binary packages for Windows. Windows users are encouraged to move to 8.2.X or later, since there are Windows-specific fixes in 8.2.X that are impractical to back-port. 8.0.X will continue to be supported on other platforms.

E.163.1. Migration to Version 8.0.15

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.163.2. Changes

- Prevent functions in indexes from executing with the privileges of the user running `VACUUM`, `ANALYZE`, etc (Tom)

  Functions used in index expressions and partial-index predicates are evaluated whenever a new table entry is made. It has long been understood that this poses a risk of trojan-horse code execution if one modifies a table owned by an untrustworthy user. (Note that triggers, defaults, check constraints, etc. pose the same type of risk.) But functions in indexes pose extra danger because they will be executed by routine maintenance operations such as `VACUUM FULL`, which are commonly performed automatically under a superuser account. For example, a nefarious user can execute code with superuser privileges by setting up a trojan-horse index definition and waiting for the next routine vacuum. The fix arranges for standard maintenance operations (including `VACUUM`, `ANALYZE`, `REINDEX`, and `CLUSTER`) to execute as the table owner rather than the calling user, using the same privilege-switching mechanism already used for `SECURITY DEFINER` functions. To prevent bypassing this security measure, execution of `SET SESSION AUTHORIZATION` and `SET ROLE` is now forbidden within a `SECURITY DEFINER` context. (CVE-2007-6600)

- Repair assorted bugs in the regular-expression package (Tom, Will Drewry)

  Suitably crafted regular-expression patterns could cause crashes, infinite or near-infinite looping, and/or massive memory consumption, all of which pose denial-of-service hazards for applications that accept regex search patterns from untrustworthy sources. (CVE-2007-4769, CVE-2007-4772, CVE-2007-6067)

- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

  The fix that appeared for this in 8.0.14 was incomplete, as it plugged the hole for only some `dblink` functions. (CVE-2007-6601, CVE-2007-3278)

- Update time zone data files to tzdata release 2007k (in particular, recent Argentina changes) (Tom)

- Fix planner failure in some cases of `WHERE false AND var IN (SELECT ...)` (Tom)

- Preserve the tablespace of indexes that are rebuilt by `ALTER TABLE ... ALTER COLUMN TYPE` (Tom)

- Make archive recovery always start a new WAL timeline, rather than only when a recovery stop time was used (Simon)

  This avoids a corner-case risk of trying to overwrite an existing archived copy of the last WAL segment, and seems simpler and cleaner than the original definition.

- Make `VACUUM` not use all of `maintenance_work_mem` when the table is too small for it to be useful (Alvaro)
- Fix potential crash in `translate()` when using a multibyte database encoding (Tom)
- Fix PL/Perl to cope when platform's Perl defines type `bool` as `int` rather than `char` (Tom)

  While this could theoretically happen anywhere, no standard build of Perl did things this way ... until Mac OS X 10.5.

- Fix PL/Python to not crash on long exception messages (Alvaro)
- Fix pg_dump to correctly handle inheritance child tables that have default expressions different from their parent's (Tom)
- ecpg parser fixes (Michael)
- Make `contrib/tablefunc`'s `crosstab()` handle NULL rowid as a category in its own right, rather than crashing (Joe)
- Fix `tsvector` and `tsquery` output routines to escape backslashes correctly (Teodor, Bruce)
- Fix crash of `to_tsvector()` on huge input strings (Teodor)
- Require a specific version of Autoconf to be used when re-generating the `configure` script (Peter)

  This affects developers and packagers only. The change was made to prevent accidental use of untested combinations of Autoconf and PostgreSQL versions. You can remove the version check if you really want to use a different Autoconf version, but it's your responsibility whether the result works or not.

E.164. Release 8.0.14

Release Date: 2007-09-17

This release contains a variety of fixes from 8.0.13. For information about new features in the 8.0 major release, see Section E.178.

E.164.1. Migration to Version 8.0.14

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.164.2. Changes

- Prevent index corruption when a transaction inserts rows and then aborts close to the end of a concurrent `VACUUM` on the same table (Tom)

- Make `CREATE DOMAIN ... DEFAULT NULL` work properly (Tom)
- Fix excessive logging of SSL error messages (Tom)
- Fix logging so that log messages are never interleaved when using the syslogger process (Andrew)
- Fix crash when `log_min_error_statement` logging runs out of memory (Tom)
- Fix incorrect handling of some foreign-key corner cases (Tom)
- Prevent `CLUSTER` from failing due to attempting to process temporary tables of other sessions (Alvaro)
- Update the time zone database rules, particularly New Zealand's upcoming changes (Tom)
- Windows socket improvements (Magnus)
- Suppress timezone name (`%Z`) in log timestamps on Windows because of possible encoding mismatches (Tom)
- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

E.165. Release 8.0.13

Release Date: 2007-04-23

This release contains a variety of fixes from 8.0.12, including a security fix. For information about new features in the 8.0 major release, see Section E.178.

E.165.1. Migration to Version 8.0.13

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.165.2. Changes

- Support explicit placement of the temporary-table schema within `search_path`, and disable searching it for functions and operators (Tom)

  This is needed to allow a security-definer function to set a truly secure value of `search_path`. Without it, an unprivileged SQL user can use temporary objects to execute code with the privileges of the security-definer function (CVE-2007-2138). See `CREATE FUNCTION` for more information.
- `/contrib/tsearch2` crash fixes (Teodor)
- Fix potential-data-corruption bug in how `VACUUM FULL` handles `UPDATE` chains (Tom, Pavan Deolasee)
- Fix PANIC during enlargement of a hash index (bug introduced in 8.0.10) (Tom)
- Fix POSIX-style timezone specs to follow new USA DST rules (Tom)

E.166. Release 8.0.12

Release Date: 2007-02-07

This release contains one fix from 8.0.11. For information about new features in the 8.0 major release, see Section E.178.

E.166.1. Migration to Version 8.0.12

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.166.2. Changes

- Remove overly-restrictive check for type length in constraints and functional indexes(Tom)

E.167. Release 8.0.11

Release Date: 2007-02-05

This release contains a variety of fixes from 8.0.10, including a security fix. For information about new features in the 8.0 major release, see Section E.178.

E.167.1. Migration to Version 8.0.11

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.167.2. Changes

- Remove security vulnerabilities that allowed connected users to read backend memory (Tom)

  The vulnerabilities involve suppressing the normal check that a SQL function returns the data type it's declared to, and changing the data type of a table column (CVE-2007-0555, CVE-2007-0556). These errors can easily be exploited to cause a backend crash, and in principle might be used to read database content that the user should not be able to access.
- Fix rare bug wherein btree index page splits could fail due to choosing an infeasible split point (Heikki Linnakangas)
- Fix for rare Assert() crash triggered by `UNION` (Tom)

- Tighten security of multi-byte character processing for UTF8 sequences over three bytes long (Tom)

E.168. Release 8.0.10

Release Date: 2007-01-08

This release contains a variety of fixes from 8.0.9. For information about new features in the 8.0 major release, see Section E.178.

E.168.1. Migration to Version 8.0.10

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.168.2. Changes

- Improve handling of `getaddrinfo()` on AIX (Tom)

  This fixes a problem with starting the statistics collector, among other things.
- Fix "failed to re-find parent key" errors in `VACUUM` (Tom)
- Fix race condition for truncation of a large relation across a gigabyte boundary by `VACUUM` (Tom)
- Fix bugs affecting multi-gigabyte hash indexes (Tom)
- Fix possible deadlock in Windows signal handling (Teodor)
- Fix error when constructing an `ARRAY[]` made up of multiple empty elements (Tom)
- Fix ecpg memory leak during connection (Michael)
- `to_number()` and `to_char(numeric)` are now `STABLE`, not `IMMUTABLE`, for new initdb installs (Tom)

  This is because `lc_numeric` can potentially change the output of these functions.
- Improve index usage of regular expressions that use parentheses (Tom)

  This improves psql `\d` performance also.
- Update timezone database

  This affects Australian and Canadian daylight-savings rules in particular.

E.169. Release 8.0.9

Release Date: 2006-10-16

This release contains a variety of fixes from 8.0.8. For information about new features in the 8.0 major release, see Section E.178.

E.169.1. Migration to Version 8.0.9

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.169.2. Changes

- Fix crash when referencing `NEW` row values in rule WHERE expressions (Tom)
- Fix core dump when an untyped literal is taken as ANYARRAY
- Fix mishandling of AFTER triggers when query contains a SQL function returning multiple rows (Tom)
- Fix `ALTER TABLE ... TYPE` to recheck `NOT NULL` for `USING` clause (Tom)
- Fix `string_to_array()` to handle overlapping matches for the separator string

  For example, `string_to_array('123xx456xxx789', 'xx')`.
- Fix corner cases in pattern matching for psql's `\d` commands
- Fix index-corrupting bugs in /contrib/ltree (Teodor)
- Numerous robustness fixes in ecpg (Joachim Wieland)
- Fix backslash escaping in /contrib/dbmirror
- Fix instability of statistics collection on Win32 (Tom, Andrew)
- Fixes for AIX and Intel compilers (Tom)

E.170. Release 8.0.8

Release Date: 2006-05-23

This release contains a variety of fixes from 8.0.7, including patches for extremely serious security issues. For information about new features in the 8.0 major release, see Section E.178.

E.170.1. Migration to Version 8.0.8

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

Full security against the SQL-injection attacks described in CVE-2006-2313 and CVE-2006-2314 might require changes in application code. If you have applications that embed untrustworthy strings into SQL commands, you should examine them as soon as possible to ensure that they are using

recommended escaping techniques. In most cases, applications should be using subroutines provided by libraries or drivers (such as libpq's `PQescapeStringConn()`) to perform string escaping, rather than relying on *ad hoc* code to do it.

E.170.2. Changes

- Change the server to reject invalidly-encoded multibyte characters in all cases (Tatsuo, Tom)

  While PostgreSQL has been moving in this direction for some time, the checks are now applied uniformly to all encodings and all textual input, and are now always errors not merely warnings. This change defends against SQL-injection attacks of the type described in CVE-2006-2313.

- Reject unsafe uses of `\'` in string literals

  As a server-side defense against SQL-injection attacks of the type described in CVE-2006-2314, the server now only accepts `''` and not `\'` as a representation of ASCII single quote in SQL string literals. By default, `\'` is rejected only when `client_encoding` is set to a client-only encoding (SJIS, BIG5, GBK, GB18030, or UHC), which is the scenario in which SQL injection is possible. A new configuration parameter `backslash_quote` is available to adjust this behavior when needed. Note that full security against CVE-2006-2314 might require client-side changes; the purpose of `backslash_quote` is in part to make it obvious that insecure clients are insecure.

- Modify libpq's string-escaping routines to be aware of encoding considerations and `standard_conforming_strings`

  This fixes libpq-using applications for the security issues described in CVE-2006-2313 and CVE-2006-2314, and also future-proofs them against the planned changeover to SQL-standard string literal syntax. Applications that use multiple PostgreSQL connections concurrently should migrate to `PQescapeStringConn()` and `PQescapeByteaConn()` to ensure that escaping is done correctly for the settings in use in each database connection. Applications that do string escaping "by hand" should be modified to rely on library routines instead.

- Fix some incorrect encoding conversion functions

  `win1251_to_iso`, `alt_to_iso`, `euc_tw_to_big5`, `euc_tw_to_mic`, `mic_to_euc_tw` were all broken to varying extents.

- Clean up stray remaining uses of `\'` in strings (Bruce, Jan)

- Fix bug that sometimes caused OR'd index scans to miss rows they should have returned

- Fix WAL replay for case where a btree index has been truncated

- Fix `SIMILAR TO` for patterns involving `|` (Tom)

- Fix `SELECT INTO` and `CREATE TABLE AS` to create tables in the default tablespace, not the base directory (Kris Jurka)

- Fix server to use custom DH SSL parameters correctly (Michael Fuhr)

- Fix for Bonjour on Intel Macs (Ashley Clark)

- Fix various minor memory leaks

- Fix problem with password prompting on some Win32 systems (Robert Kinberg)

E.171. Release 8.0.7

Release Date: 2006-02-14

This release contains a variety of fixes from 8.0.6. For information about new features in the 8.0 major release, see Section E.178.

E.171.1. Migration to Version 8.0.7

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.6, see Section E.172.

E.171.2. Changes

- Fix potential crash in `SET SESSION AUTHORIZATION` (CVE-2006-0553)

  An unprivileged user could crash the server process, resulting in momentary denial of service to other users, if the server has been compiled with Asserts enabled (which is not the default). Thanks to Akio Ishida for reporting this problem.

- Fix bug with row visibility logic in self-inserted rows (Tom)

  Under rare circumstances a row inserted by the current command could be seen as already valid, when it should not be. Repairs bug created in 8.0.4, 7.4.9, and 7.3.11 releases.

- Fix race condition that could lead to "file already exists" errors during pg_clog and pg_subtrans file creation (Tom)

- Fix cases that could lead to crashes if a cache-invalidation message arrives at just the wrong time (Tom)

- Properly check `DOMAIN` constraints for `UNKNOWN` parameters in prepared statements (Neil)

- Ensure `ALTER COLUMN TYPE` will process `FOREIGN KEY`, `UNIQUE`, and `PRIMARY KEY` constraints in the proper order (Nakano Yoshihisa)

- Fixes to allow restoring dumps that have cross-schema references to custom operators or operator classes (Tom)

- Allow pg_restore to continue properly after a `COPY` failure; formerly it tried to treat the remaining `COPY` data as SQL commands (Stephen Frost)

- Fix pg_ctl `unregister` crash when the data directory is not specified (Magnus)

- Fix ecpg crash on AMD64 and PPC (Neil)

- Recover properly if error occurs during argument passing in PL/python (Neil)

- Fix PL/perl's handling of locales on Win32 to match the backend (Andrew)

- Fix crash when `log_min_messages` is set to `DEBUG3` or above in `postgresql.conf` on Win32 (Bruce)

- Fix pgxs `-L` library path specification for Win32, Cygwin, OS X, AIX (Bruce)

- Check that SID is enabled while checking for Win32 admin privileges (Magnus)

- Properly reject out-of-range date inputs (Kris Jurka)

- Portability fix for testing presence of `finite` and `isinf` during configure (Tom)

E.172. Release 8.0.6

Release Date: 2006-01-09

This release contains a variety of fixes from 8.0.5. For information about new features in the 8.0 major release, see Section E.178.

E.172.1. Migration to Version 8.0.6

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.3, see Section E.175. Also, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the locale or plperl issues described below.

E.172.2. Changes

- Fix Windows code so that postmaster will continue rather than exit if there is no more room in ShmemBackendArray (Magnus)

  The previous behavior could lead to a denial-of-service situation if too many connection requests arrive close together. This applies *only* to the Windows port.
- Fix bug introduced in 8.0 that could allow ReadBuffer to return an already-used page as new, potentially causing loss of recently-committed data (Tom)
- Fix for protocol-level Describe messages issued outside a transaction or in a failed transaction (Tom)
- Fix character string comparison for locales that consider different character combinations as equal, such as Hungarian (Tom)

  This might require `REINDEX` to fix existing indexes on textual columns.
- Set locale environment variables during postmaster startup to ensure that plperl won't change the locale later

  This fixes a problem that occurred if the postmaster was started with environment variables specifying a different locale than what initdb had been told. Under these conditions, any use of plperl was likely to lead to corrupt indexes. You might need `REINDEX` to fix existing indexes on textual columns if this has happened to you.
- Allow more flexible relocation of installation directories (Tom)

  Previous releases supported relocation only if all installation directory paths were the same except for the last component.
- Fix longstanding bug in strpos() and regular expression handling in certain rarely used Asian multibyte character sets (Tatsuo)
- Various fixes for functions returning `RECORD`s (Tom)

- Fix bug in `/contrib/pgcrypto` gen_salt, which caused it not to use all available salt space for MD5 and XDES algorithms (Marko Kreen, Solar Designer)

  Salts for Blowfish and standard DES are unaffected.

- Fix `/contrib/dblink` to throw an error, rather than crashing, when the number of columns specified is different from what's actually returned by the query (Joe)

E.173. Release 8.0.5

Release Date: 2005-12-12

This release contains a variety of fixes from 8.0.4. For information about new features in the 8.0 major release, see Section E.178.

E.173.1. Migration to Version 8.0.5

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.3, see Section E.175.

E.173.2. Changes

- Fix race condition in transaction log management

  There was a narrow window in which an I/O operation could be initiated for the wrong page, leading to an Assert failure or data corruption.

- Fix bgwriter problems after recovering from errors (Tom)

  The background writer was found to leak buffer pins after write errors. While not fatal in itself, this might lead to mysterious blockages of later VACUUM commands.

- Prevent failure if client sends Bind protocol message when current transaction is already aborted
- `/contrib/ltree` fixes (Teodor)
- AIX and HPUX compile fixes (Tom)
- Retry file reads and writes after Windows NO_SYSTEM_RESOURCES error (Qingqing Zhou)
- Fix intermittent failure when `log_line_prefix` includes `%i`
- Fix psql performance issue with long scripts on Windows (Merlin Moncure)
- Fix missing updates of `pg_group` flat file
- Fix longstanding planning error for outer joins

  This bug sometimes caused a bogus error "RIGHT JOIN is only supported with merge-joinable join conditions".

- Postpone timezone initialization until after `postmaster.pid` is created

  This avoids confusing startup scripts that expect the pid file to appear quickly.

- Prevent core dump in pg_autovacuum when a table has been dropped
- Fix problems with whole-row references (`foo.*`) to subquery results

E.174. Release 8.0.4

Release Date: 2005-10-04

This release contains a variety of fixes from 8.0.3. For information about new features in the 8.0 major release, see Section E.178.

E.174.1. Migration to Version 8.0.4

A dump/restore is not required for those running 8.0.X. However, if you are upgrading from a version earlier than 8.0.3, see Section E.175.

E.174.2. Changes

- Fix error that allowed `VACUUM` to remove `ctid` chains too soon, and add more checking in code that follows `ctid` links

  This fixes a long-standing problem that could cause crashes in very rare circumstances.
- Fix `CHAR()` to properly pad spaces to the specified length when using a multiple-byte character set (Yoshiyuki Asaba)

  In prior releases, the padding of `CHAR()` was incorrect because it only padded to the specified number of bytes without considering how many characters were stored.
- Force a checkpoint before committing `CREATE DATABASE`

  This should fix recent reports of "index is not a btree" failures when a crash occurs shortly after `CREATE DATABASE`.
- Fix the sense of the test for read-only transaction in `COPY`

  The code formerly prohibited `COPY TO`, where it should prohibit `COPY FROM`.
- Handle consecutive embedded newlines in `COPY` CSV-mode input
- Fix `date_trunc(week)` for dates near year end
- Fix planning problem with outer-join ON clauses that reference only the inner-side relation
- Further fixes for `x FULL JOIN y ON true` corner cases
- Fix overenthusiastic optimization of `x IN (SELECT DISTINCT ...)` and related cases
- Fix mis-planning of queries with small `LIMIT` values due to poorly thought out "fuzzy" cost comparison
- Make `array_in` and `array_recv` more paranoid about validating their OID parameter
- Fix missing rows in queries like `UPDATE a=... WHERE a...` with GiST index on column `a`

- Improve robustness of datetime parsing
- Improve checking for partially-written WAL pages
- Improve robustness of signal handling when SSL is enabled
- Improve MIPS and M68K spinlock code
- Don't try to open more than `max_files_per_process` files during postmaster startup
- Various memory leakage fixes
- Various portability improvements
- Update timezone data files
- Improve handling of DLL load failures on Windows
- Improve random-number generation on Windows
- Make `psql -f filename` return a nonzero exit code when opening the file fails
- Change pg_dump to handle inherited check constraints more reliably
- Fix password prompting in pg_restore on Windows
- Fix PL/pgSQL to handle `var := var` correctly when the variable is of pass-by-reference type
- Fix PL/Perl `%_SHARED` so it's actually shared
- Fix `contrib/pg_autovacuum` to allow sleep intervals over 2000 sec
- Update `contrib/tsearch2` to use current Snowball code

E.175. Release 8.0.3

Release Date: 2005-05-09

This release contains a variety of fixes from 8.0.2, including several security-related issues. For information about new features in the 8.0 major release, see Section E.178.

E.175.1. Migration to Version 8.0.3

A dump/restore is not required for those running 8.0.X. However, it is one possible way of handling two significant security problems that have been found in the initial contents of 8.0.X system catalogs. A dump/initdb/reload sequence using 8.0.3's initdb will automatically correct these problems.

The larger security problem is that the built-in character set encoding conversion functions can be invoked from SQL commands by unprivileged users, but the functions were not designed for such use and are not secure against malicious choices of arguments. The fix involves changing the declared parameter list of these functions so that they can no longer be invoked from SQL commands. (This does not affect their normal use by the encoding conversion machinery.)

The lesser problem is that the `contrib/tsearch2` module creates several functions that are improperly declared to return `internal` when they do not accept `internal` arguments. This breaks type safety for all functions using `internal` arguments.

It is strongly recommended that all installations repair these errors, either by initdb or by following the manual repair procedure given below. The errors at least allow unprivileged database users to crash their server process, and might allow unprivileged users to gain the privileges of a database superuser.

If you wish not to do an initdb, perform the same manual repair procedures shown in the 7.4.8 release notes.

E.175.2. Changes

- Change encoding function signature to prevent misuse
- Change `contrib/tsearch2` to avoid unsafe use of `INTERNAL` function results
- Guard against incorrect second parameter to `record_out`
- Repair ancient race condition that allowed a transaction to be seen as committed for some purposes (eg SELECT FOR UPDATE) slightly sooner than for other purposes

  This is an extremely serious bug since it could lead to apparent data inconsistencies being briefly visible to applications.
- Repair race condition between relation extension and VACUUM

  This could theoretically have caused loss of a page's worth of freshly-inserted data, although the scenario seems of very low probability. There are no known cases of it having caused more than an Assert failure.
- Fix comparisons of `TIME WITH TIME ZONE` values

  The comparison code was wrong in the case where the `--enable-integer-datetimes` configuration switch had been used. NOTE: if you have an index on a `TIME WITH TIME ZONE` column, it will need to be `REINDEX`ed after installing this update, because the fix corrects the sort order of column values.
- Fix `EXTRACT(EPOCH)` for `TIME WITH TIME ZONE` values
- Fix mis-display of negative fractional seconds in `INTERVAL` values

  This error only occurred when the `--enable-integer-datetimes` configuration switch had been used.
- Fix pg_dump to dump trigger names containing `%` correctly (Neil)
- Still more 64-bit fixes for `contrib/intagg`
- Prevent incorrect optimization of functions returning `RECORD`
- Prevent crash on `COALESCE(NULL,NULL)`
- Fix Borland makefile for libpq
- Fix `contrib/btree_gist` for `timetz` type (Teodor)
- Make `pg_ctl` check the PID found in `postmaster.pid` to see if it is still a live process
- Fix `pg_dump`/`pg_restore` problems caused by addition of dump timestamps
- Fix interaction between materializing holdable cursors and firing deferred triggers during transaction commit
- Fix memory leak in SQL functions returning pass-by-reference data types

E.176. Release 8.0.2

Release Date: 2005-04-07

This release contains a variety of fixes from 8.0.1. For information about new features in the 8.0 major release, see Section E.178.

E.176.1. Migration to Version 8.0.2

A dump/restore is not required for those running 8.0.*. This release updates the major version number of the PostgreSQL libraries, so it might be necessary to re-link some user applications if they cannot find the properly-numbered shared library.

E.176.2. Changes

- Increment the major version number of all interface libraries (Bruce)

  This should have been done in 8.0.0. It is required so 7.4.X versions of PostgreSQL client applications, like psql, can be used on the same machine as 8.0.X applications. This might require re-linking user applications that use these libraries.

- Add Windows-only `wal_sync_method` setting of `fsync_writethrough` (Magnus, Bruce)

  This setting causes PostgreSQL to write through any disk-drive write cache when writing to WAL. This behavior was formerly called `fsync`, but was renamed because it acts quite differently from `fsync` on other platforms.

- Enable the `wal_sync_method` setting of `open_datasync` on Windows, and make it the default for that platform (Magnus, Bruce)

  Because the default is no longer `fsync_writethrough`, data loss is possible during a power failure if the disk drive has write caching enabled. To turn off the write cache on Windows, from the Device Manager, choose the drive properties, then `Policies`.

- New cache management algorithm 2Q replaces ARC (Tom)

  This was done to avoid a pending US patent on ARC. The 2Q code might be a few percentage points slower than ARC for some work loads. A better cache management algorithm will appear in 8.1.

- Planner adjustments to improve behavior on freshly-created tables (Tom)

- Allow plpgsql to assign to an element of an array that is initially `NULL` (Tom)

  Formerly the array would remain `NULL`, but now it becomes a single-element array. The main SQL engine was changed to handle `UPDATE` of a null array value this way in 8.0, but the similar case in plpgsql was overlooked.

- Convert `\r\n` and `\r` to `\n` in plpython function bodies (Michael Fuhr)

  This prevents syntax errors when plpython code is written on a Windows or Mac client.

- Allow SPI cursors to handle utility commands that return rows, such as `EXPLAIN` (Tom)

- Fix `CLUSTER` failure after `ALTER TABLE SET WITHOUT OIDS` (Tom)

- Reduce memory usage of `ALTER TABLE ADD COLUMN` (Neil)
- Fix `ALTER LANGUAGE RENAME` (Tom)
- Document the Windows-only `register` and `unregister` options of pg_ctl (Magnus)
- Ensure operations done during backend shutdown are counted by statistics collector

  This is expected to resolve reports of pg_autovacuum not vacuuming the system catalogs often enough — it was not being told about catalog deletions caused by temporary table removal during backend exit.
- Change the Windows default for configuration parameter `log_destination` to `eventlog` (Magnus)

  By default, a server running on Windows will now send log output to the Windows event logger rather than standard error.
- Make Kerberos authentication work on Windows (Magnus)
- Allow `ALTER DATABASE RENAME` by superusers who aren't flagged as having CREATEDB privilege (Tom)
- Modify WAL log entries for `CREATE` and `DROP DATABASE` to not specify absolute paths (Tom)

  This allows point-in-time recovery on a different machine with possibly different database location. Note that `CREATE TABLESPACE` still poses a hazard in such situations.
- Fix crash from a backend exiting with an open transaction that created a table and opened a cursor on it (Tom)
- Fix `array_map()` so it can call PL functions (Tom)
- Several `contrib/tsearch2` and `contrib/btree_gist` fixes (Teodor)
- Fix crash of some `contrib/pgcrypto` functions on some platforms (Marko Kreen)
- Fix `contrib/intagg` for 64-bit platforms (Tom)
- Fix ecpg bugs in parsing of `CREATE` statement (Michael)
- Work around gcc bug on powerpc and amd64 causing problems in ecpg (Christof Petig)
- Do not use locale-aware versions of `upper()`, `lower()`, and `initcap()` when the locale is `C` (Bruce)

  This allows these functions to work on platforms that generate errors for non-7-bit data when the locale is `C`.
- Fix `quote_ident()` to quote names that match keywords (Tom)
- Fix `to_date()` to behave reasonably when `CC` and `YY` fields are both used (Karel)
- Prevent `to_char(interval)` from failing when given a zero-month interval (Tom)
- Fix wrong week returned by `date_trunc('week')` (Bruce)

  `date_trunc('week')` returned the wrong year for the first few days of January in some years.
- Use the correct default mask length for class `D` addresses in `INET` data types (Tom)

E.177. Release 8.0.1

Release Date: 2005-01-31

This release contains a variety of fixes from 8.0.0, including several security-related issues. For information about new features in the 8.0 major release, see Section E.178.

E.177.1. Migration to Version 8.0.1

A dump/restore is not required for those running 8.0.0.

E.177.2. Changes

- Disallow `LOAD` to non-superusers

  On platforms that will automatically execute initialization functions of a shared library (this includes at least Windows and ELF-based Unixen), `LOAD` can be used to make the server execute arbitrary code. Thanks to NGS Software for reporting this.

- Check that creator of an aggregate function has the right to execute the specified transition functions

  This oversight made it possible to bypass denial of EXECUTE permission on a function.

- Fix security and 64-bit issues in contrib/intagg
- Add needed STRICT marking to some contrib functions (Kris Jurka)
- Avoid buffer overrun when plpgsql cursor declaration has too many parameters (Neil)
- Make `ALTER TABLE ADD COLUMN` enforce domain constraints in all cases
- Fix planning error for FULL and RIGHT outer joins

  The result of the join was mistakenly supposed to be sorted the same as the left input. This could not only deliver mis-sorted output to the user, but in case of nested merge joins could give outright wrong answers.

- Improve planning of grouped aggregate queries
- `ROLLBACK TO` *`savepoint`* closes cursors created since the savepoint
- Fix inadequate backend stack size on Windows
- Avoid SHGetSpecialFolderPath() on Windows (Magnus)
- Fix some problems in running pg_autovacuum as a Windows service (Dave Page)
- Multiple minor bug fixes in pg_dump/pg_restore
- Fix ecpg segfault with named structs used in typedefs (Michael)

E.178. Release 8.0

Release Date: 2005-01-19

E.178.1. Overview

Major changes in this release:

Microsoft Windows Native Server

This is the first PostgreSQL release to run natively on Microsoft Windows® as a server. It can run as a Windows service. This release supports NT-based Windows releases like Windows 2000 SP4, Windows XP, and Windows 2003. Older releases like Windows 95, Windows 98, and Windows ME are not supported because these operating systems do not have the infrastructure to support PostgreSQL. A separate installer project has been created to ease installation on Windows — see http://www.postgresql.org/ftp/win32/.

Although tested throughout our release cycle, the Windows port does not have the benefit of years of use in production environments that PostgreSQL has on Unix platforms. Therefore it should be treated with the same level of caution as you would a new product.

Previous releases required the Unix emulation toolkit Cygwin in order to run the server on Windows operating systems. PostgreSQL has supported native clients on Windows for many years.

Savepoints

Savepoints allow specific parts of a transaction to be aborted without affecting the remainder of the transaction. Prior releases had no such capability; there was no way to recover from a statement failure within a transaction except by aborting the whole transaction. This feature is valuable for application writers who require error recovery within a complex transaction.

Point-In-Time Recovery

In previous releases there was no way to recover from disk drive failure except to restore from a previous backup or use a standby replication server. Point-in-time recovery allows continuous backup of the server. You can recover either to the point of failure or to some transaction in the past.

Tablespaces

Tablespaces allow administrators to select different file systems for storage of individual tables, indexes, and databases. This improves performance and control over disk space usage. Prior releases used initlocation and manual symlink management for such tasks.

Improved Buffer Management, `CHECKPOINT`, `VACUUM`

This release has a more intelligent buffer replacement strategy, which will make better use of available shared buffers and improve performance. The performance impact of vacuum and checkpoints is also lessened.

Change Column Types

A column's data type can now be changed with `ALTER TABLE`.

New Perl Server-Side Language

A new version of the plperl server-side language now supports a persistent shared storage area, triggers, returning records and arrays of records, and SPI calls to access the database.

Comma-separated-value (CSV) support in `COPY`

`COPY` can now read and write comma-separated-value files. It has the flexibility to interpret non-standard quoting and separation characters too.

E.178.2. Migration to Version 8.0

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

- In `READ COMMITTED` serialization mode, volatile functions now see the results of concurrent transactions committed up to the beginning of each statement within the function, rather than up to the beginning of the interactive command that called the function.
- Functions declared `STABLE` or `IMMUTABLE` always use the snapshot of the calling query, and therefore do not see the effects of actions taken after the calling query starts, whether in their own transaction or other transactions. Such a function must be read-only, too, meaning that it cannot use any SQL commands other than `SELECT`.
- Nondeferred `AFTER` triggers are now fired immediately after completion of the triggering query, rather than upon finishing the current interactive command. This makes a difference when the triggering query occurred within a function: the trigger is invoked before the function proceeds to its next operation.
- Server configuration parameters `virtual_host` and `tcpip_socket` have been replaced with a more general parameter `listen_addresses`. Also, the server now listens on `localhost` by default, which eliminates the need for the `-i` postmaster switch in many scenarios.
- Server configuration parameters `SortMem` and `VacuumMem` have been renamed to `work_mem` and `maintenance_work_mem` to better reflect their use. The original names are still supported in `SET` and `SHOW`.
- Server configuration parameters `log_pid`, `log_timestamp`, and `log_source_port` have been replaced with a more general parameter `log_line_prefix`.
- Server configuration parameter `syslog` has been replaced with a more logical `log_destination` variable to control the log output destination.
- Server configuration parameter `log_statement` has been changed so it can selectively log just database modification or data definition statements. Server configuration parameter `log_duration` now prints only when `log_statement` prints the query.
- Server configuration parameter `max_expr_depth` parameter has been replaced with `max_stack_depth` which measures the physical stack size rather than the expression nesting depth. This helps prevent session termination due to stack overflow caused by recursive functions.
- The `length()` function no longer counts trailing spaces in `CHAR(n)` values.
- Casting an integer to `BIT(N)` selects the rightmost N bits of the integer, not the leftmost N bits as before.
- Updating an element or slice of a NULL array value now produces a nonnull array result, namely an array containing just the assigned-to positions.
- Syntax checking of array input values has been tightened up considerably. Junk that was previously allowed in odd places with odd results now causes an error. Empty-string element values must now be written as `""`, rather than writing nothing. Also changed behavior with respect to whitespace surrounding array elements: trailing whitespace is now ignored, for symmetry with leading whitespace (which has always been ignored).
- Overflow in integer arithmetic operations is now detected and reported as an error.
- The arithmetic operators associated with the single-byte `"char"` data type have been removed.

- The `extract()` function (also called `date_part`) now returns the proper year for BC dates. It previously returned one less than the correct year. The function now also returns the proper values for millennium and century.
- `CIDR` values now must have their nonmasked bits be zero. For example, we no longer allow `204.248.199.1/31` as a `CIDR` value. Such values should never have been accepted by PostgreSQL and will now be rejected.
- `EXECUTE` now returns a completion tag that matches the executed statement.
- psql's `\copy` command now reads or writes to the query's `stdin/stdout`, rather than psql's `stdin/stdout`. The previous behavior can be accessed via new `pstdin`/`pstdout` parameters.
- The JDBC client interface has been removed from the core distribution, and is now hosted at http://jdbc.postgresql.org.
- The Tcl client interface has also been removed. There are several Tcl interfaces now hosted at http://gborg.postgresql.org.
- The server now uses its own time zone database, rather than the one supplied by the operating system. This will provide consistent behavior across all platforms. In most cases, there should be little noticeable difference in time zone behavior, except that the time zone names used by `SET`/`SHOW TimeZone` might be different from what your platform provides.
- Configure's threading option no longer requires users to run tests or edit configuration files; threading options are now detected automatically.
- Now that tablespaces have been implemented, initlocation has been removed.
- The API for user-defined GiST indexes has been changed. The Union and PickSplit methods are now passed a pointer to a special `GistEntryVector` structure, rather than a `bytea`.

E.178.3. Deprecated Features

Some aspects of PostgreSQL's behavior have been determined to be suboptimal. For the sake of backward compatibility these have not been removed in 8.0, but they are considered deprecated and will be removed in the next major release.

- The 8.1 release will remove the `to_char()` function for intervals.
- The server now warns of empty strings passed to `oid`/`float4`/`float8` data types, but continues to interpret them as zeroes as before. In the next major release, empty strings will be considered invalid input for these data types.
- By default, tables in PostgreSQL 8.0 and earlier are created with `OIDs`. In the next release, this will *not* be the case: to create a table that contains `OIDs`, the `WITH OIDS` clause must be specified or the `default_with_oids` configuration parameter must be set. Users are encouraged to explicitly specify `WITH OIDS` if their tables require OIDs for compatibility with future releases of PostgreSQL.

E.178.4. Changes

Below you will find a detailed account of the changes between release 8.0 and the previous major release.

E.178.4.1. Performance Improvements

- Support cross-data-type index usage (Tom)

  Before this change, many queries would not use an index if the data types did not match exactly. This improvement makes index usage more intuitive and consistent.

- New buffer replacement strategy that improves caching (Jan)

  Prior releases used a least-recently-used (LRU) cache to keep recently referenced pages in memory. The LRU algorithm did not consider the number of times a specific cache entry was accessed, so large table scans could force out useful cache pages. The new cache algorithm uses four separate lists to track most recently used and most frequently used cache pages and dynamically optimize their replacement based on the work load. This should lead to much more efficient use of the shared buffer cache. Administrators who have tested shared buffer sizes in the past should retest with this new cache replacement policy.

- Add subprocess to write dirty buffers periodically to reduce checkpoint writes (Jan)

  In previous releases, the checkpoint process, which runs every few minutes, would write all dirty buffers to the operating system's buffer cache then flush all dirty operating system buffers to disk. This resulted in a periodic spike in disk usage that often hurt performance. The new code uses a background writer to trickle disk writes at a steady pace so checkpoints have far fewer dirty pages to write to disk. Also, the new code does not issue a global `sync()` call, but instead `fsync()`s just the files written since the last checkpoint. This should improve performance and minimize degradation during checkpoints.

- Add ability to prolong vacuum to reduce performance impact (Jan)

  On busy systems, `VACUUM` performs many I/O requests which can hurt performance for other users. This release allows you to slow down `VACUUM` to reduce its impact on other users, though this increases the total duration of `VACUUM`.

- Improve B-tree index performance for duplicate keys (Dmitry Tkach, Tom)

  This improves the way indexes are scanned when many duplicate values exist in the index.

- Use dynamically-generated table size estimates while planning (Tom)

  Formerly the planner estimated table sizes using the values seen by the last `VACUUM` or `ANALYZE`, both as to physical table size (number of pages) and number of rows. Now, the current physical table size is obtained from the kernel, and the number of rows is estimated by multiplying the table size by the row density (rows per page) seen by the last `VACUUM` or `ANALYZE`. This should produce more reliable estimates in cases where the table size has changed significantly since the last housekeeping command.

- Improved index usage with `OR` clauses (Tom)

  This allows the optimizer to use indexes in statements with many OR clauses that would not have been indexed in the past. It can also use multi-column indexes where the first column is specified and the second column is part of an `OR` clause.

- Improve matching of partial index clauses (Tom)

  The server is now smarter about using partial indexes in queries involving complex `WHERE` clauses.

- Improve performance of the GEQO optimizer (Tom)

  The GEQO optimizer is used to plan queries involving many tables (by default, twelve or more). This release speeds up the way queries are analyzed to decrease time spent in optimization.

- Miscellaneous optimizer improvements

There is not room here to list all the minor improvements made, but numerous special cases work better than in prior releases.

- Improve lookup speed for C functions (Tom)

  This release uses a hash table to lookup information for dynamically loaded C functions. This improves their speed so they perform nearly as quickly as functions that are built into the server executable.

- Add type-specific `ANALYZE` statistics capability (Mark Cave-Ayland)

  This feature allows more flexibility in generating statistics for nonstandard data types.

- `ANALYZE` now collects statistics for expression indexes (Tom)

  Expression indexes (also called functional indexes) allow users to index not just columns but the results of expressions and function calls. With this release, the optimizer can gather and use statistics about the contents of expression indexes. This will greatly improve the quality of planning for queries in which an expression index is relevant.

- New two-stage sampling method for `ANALYZE` (Manfred Koizar)

  This gives better statistics when the density of valid rows is very different in different regions of a table.

- Speed up `TRUNCATE` (Tom)

  This buys back some of the performance loss observed in 7.4, while still keeping `TRUNCATE` transaction-safe.

E.178.4.2. Server Changes

- Add WAL file archiving and point-in-time recovery (Simon Riggs)
- Add tablespaces so admins can control disk layout (Gavin)
- Add a built-in log rotation program (Andreas Pflug)

  It is now possible to log server messages conveniently without relying on either syslog or an external log rotation program.

- Add new read-only server configuration parameters to show server compile-time settings: `block_size`, `integer_datetimes`, `max_function_args`, `max_identifier_length`, `max_index_keys` (Joe)
- Make quoting of `sameuser`, `samegroup`, and `all` remove special meaning of these terms in `pg_hba.conf` (Andrew)
- Use clearer IPv6 name `::1/128` for `localhost` in default `pg_hba.conf` (Andrew)
- Use CIDR format in `pg_hba.conf` examples (Andrew)
- Rename server configuration parameters `SortMem` and `VacuumMem` to `work_mem` and `maintenance_work_mem` (Old names still supported) (Tom)

  This change was made to clarify that bulk operations such as index and foreign key creation use `maintenance_work_mem`, while `work_mem` is for workspaces used during query execution.

- Allow logging of session disconnections using server configuration `log_disconnections` (Andrew)
- Add new server configuration parameter `log_line_prefix` to allow control of information emitted in each log line (Andrew)

Available information includes user name, database name, remote IP address, and session start time.

- Remove server configuration parameters `log_pid`, `log_timestamp`, `log_source_port`; functionality superseded by `log_line_prefix` (Andrew)
- Replace the `virtual_host` and `tcpip_socket` parameters with a unified `listen_addresses` parameter (Andrew, Tom)

  `virtual_host` could only specify a single IP address to listen on. `listen_addresses` allows multiple addresses to be specified.
- Listen on localhost by default, which eliminates the need for the `-i` postmaster switch in many scenarios (Andrew)

  Listening on localhost (`127.0.0.1`) opens no new security holes but allows configurations like Windows and JDBC, which do not support local sockets, to work without special adjustments.
- Remove `syslog` server configuration parameter, and add more logical `log_destination` variable to control log output location (Magnus)
- Change server configuration parameter `log_statement` to take values `all`, `mod`, `ddl`, or `none` to select which queries are logged (Bruce)

  This allows administrators to log only data definition changes or only data modification statements.
- Some logging-related configuration parameters could formerly be adjusted by ordinary users, but only in the "more verbose" direction. They are now treated more strictly: only superusers can set them. However, a superuser can use `ALTER USER` to provide per-user settings of these values for non-superusers. Also, it is now possible for superusers to set values of superuser-only configuration parameters via `PGOPTIONS`.
- Allow configuration files to be placed outside the data directory (mlw)

  By default, configuration files are kept in the cluster's top directory. With this addition, configuration files can be placed outside the data directory, easing administration.
- Plan prepared queries only when first executed so constants can be used for statistics (Oliver Jowett)

  Prepared statements plan queries once and execute them many times. While prepared queries avoid the overhead of re-planning on each use, the quality of the plan suffers from not knowing the exact parameters to be used in the query. In this release, planning of unnamed prepared statements is delayed until the first execution, and the actual parameter values of that execution are used as optimization hints. This allows use of out-of-line parameter passing without incurring a performance penalty.
- Allow `DECLARE CURSOR` to take parameters (Oliver Jowett)

  It is now useful to issue `DECLARE CURSOR` in a `Parse` message with parameters. The parameter values sent at `Bind` time will be substituted into the execution of the cursor's query.
- Fix hash joins and aggregates of `inet` and `cidr` data types (Tom)

  Release 7.4 handled hashing of mixed `inet` and `cidr` values incorrectly. (This bug did not exist in prior releases because they wouldn't try to hash either data type.)
- Make `log_duration` print only when `log_statement` prints the query (Ed L.)

E.178.4.3. Query Changes

- Add savepoints (nested transactions) (Alvaro)

- Unsupported isolation levels are now accepted and promoted to the nearest supported level (Peter)

  The SQL specification states that if a database doesn't support a specific isolation level, it should use the next more restrictive level. This change complies with that recommendation.

- Allow `BEGIN WORK` to specify transaction isolation levels like `START TRANSACTION` does (Bruce)

- Fix table permission checking for cases in which rules generate a query type different from the originally submitted query (Tom)

- Implement dollar quoting to simplify single-quote usage (Andrew, Tom, David Fetter)

  In previous releases, because single quotes had to be used to quote a function's body, the use of single quotes inside the function text required use of two single quotes or other error-prone notations. With this release we add the ability to use "dollar quoting" to quote a block of text. The ability to use different quoting delimiters at different nesting levels greatly simplifies the task of quoting correctly, especially in complex functions. Dollar quoting can be used anywhere quoted text is needed.

- Make `CASE val WHEN compval1 THEN ...` evaluate `val` only once (Tom)

  `CASE` no longer evaluates the tested expression multiple times. This has benefits when the expression is complex or is volatile.

- Test `HAVING` before computing target list of an aggregate query (Tom)

  Fixes improper failure of cases such as `SELECT SUM(win)/SUM(lose) ... GROUP BY ... HAVING SUM(lose) > 0`. This should work but formerly could fail with divide-by-zero.

- Replace `max_expr_depth` parameter with `max_stack_depth` parameter, measured in kilobytes of stack size (Tom)

  This gives us a fairly bulletproof defense against crashing due to runaway recursive functions. Instead of measuring the depth of expression nesting, we now directly measure the size of the execution stack.

- Allow arbitrary row expressions (Tom)

  This release allows SQL expressions to contain arbitrary composite types, that is, row values. It also allows functions to more easily take rows as arguments and return row values.

- Allow `LIKE`/`ILIKE` to be used as the operator in row and subselect comparisons (Fabien Coelho)

- Avoid locale-specific case conversion of basic ASCII letters in identifiers and keywords (Tom)

  This solves the "Turkish problem" with mangling of words containing `I` and `i`. Folding of characters outside the 7-bit-ASCII set is still locale-aware.

- Improve syntax error reporting (Fabien, Tom)

  Syntax error reports are more useful than before.

- Change `EXECUTE` to return a completion tag matching the executed statement (Kris Jurka)

  Previous releases return an `EXECUTE` tag for any `EXECUTE` call. In this release, the tag returned will reflect the command executed.

- Avoid emitting `NATURAL CROSS JOIN` in rule listings (Tom)

  Such a clause makes no logical sense, but in some cases the rule decompiler formerly produced this syntax.

E.178.4.4. Object Manipulation Changes

- Add COMMENT ON for casts, conversions, languages, operator classes, and large objects (Christopher)
- Add new server configuration parameter default_with_oids to control whether tables are created with OIDs by default (Neil)

  This allows administrators to control whether CREATE TABLE commands create tables with or without OID columns by default. (Note: the current factory default setting for default_with_oids is TRUE, but the default will become FALSE in future releases.)
- Add WITH / WITHOUT OIDS clause to CREATE TABLE AS (Neil)
- Allow ALTER TABLE DROP COLUMN to drop an OID column (ALTER TABLE SET WITHOUT OIDS still works) (Tom)
- Allow composite types as table columns (Tom)
- Allow ALTER ... ADD COLUMN with defaults and NOT NULL constraints; works per SQL spec (Rod)

  It is now possible for ADD COLUMN to create a column that is not initially filled with NULLs, but with a specified default value.
- Add ALTER COLUMN TYPE to change column's type (Rod)

  It is now possible to alter a column's data type without dropping and re-adding the column.
- Allow multiple ALTER actions in a single ALTER TABLE command (Rod)

  This is particularly useful for ALTER commands that rewrite the table (which include ALTER COLUMN TYPE and ADD COLUMN with a default). By grouping ALTER commands together, the table need be rewritten only once.
- Allow ALTER TABLE to add SERIAL columns (Tom)

  This falls out from the new capability of specifying defaults for new columns.
- Allow changing the owners of aggregates, conversions, databases, functions, operators, operator classes, schemas, types, and tablespaces (Christopher, Euler Taveira de Oliveira)

  Previously this required modifying the system tables directly.
- Allow temporary object creation to be limited to SECURITY DEFINER functions (Sean Chittenden)
- Add ALTER TABLE ... SET WITHOUT CLUSTER (Christopher)

  Prior to this release, there was no way to clear an auto-cluster specification except to modify the system tables.
- Constraint/Index/SERIAL names are now *table_column_type* with numbers appended to guarantee uniqueness within the schema (Tom)

  The SQL specification states that such names should be unique within a schema.
- Add pg_get_serial_sequence() to return a SERIAL column's sequence name (Christopher)

  This allows automated scripts to reliably find the SERIAL sequence name.
- Warn when primary/foreign key data type mismatch requires costly lookup
- New ALTER INDEX command to allow moving of indexes between tablespaces (Gavin)
- Make ALTER TABLE OWNER change dependent sequence ownership too (Alvaro)

E.178.4.5. Utility Command Changes

- Allow `CREATE SCHEMA` to create triggers, indexes, and sequences (Neil)
- Add `ALSO` keyword to `CREATE RULE` (Fabien Coelho)

  This allows `ALSO` to be added to rule creation to contrast it with `INSTEAD` rules.
- Add `NOWAIT` option to `LOCK` (Tatsuo)

  This allows the `LOCK` command to fail if it would have to wait for the requested lock.
- Allow `COPY` to read and write comma-separated-value (CSV) files (Andrew, Bruce)
- Generate error if the `COPY` delimiter and NULL string conflict (Bruce)
- `GRANT`/`REVOKE` behavior follows the SQL spec more closely
- Avoid locking conflict between `CREATE INDEX` and `CHECKPOINT` (Tom)

  In 7.3 and 7.4, a long-running B-tree index build could block concurrent `CHECKPOINT`s from completing, thereby causing WAL bloat because the WAL log could not be recycled.
- Database-wide `ANALYZE` does not hold locks across tables (Tom)

  This reduces the potential for deadlocks against other backends that want exclusive locks on tables. To get the benefit of this change, do not execute database-wide `ANALYZE` inside a transaction block (`BEGIN` block); it must be able to commit and start a new transaction for each table.
- `REINDEX` does not exclusively lock the index's parent table anymore

  The index itself is still exclusively locked, but readers of the table can continue if they are not using the particular index being rebuilt.
- Erase MD5 user passwords when a user is renamed (Bruce)

  PostgreSQL uses the user name as salt when encrypting passwords via MD5. When a user's name is changed, the salt will no longer match the stored MD5 password, so the stored password becomes useless. In this release a notice is generated and the password is cleared. A new password must then be assigned if the user is to be able to log in with a password.
- New pg_ctl `kill` option for Windows (Andrew)

  Windows does not have a `kill` command to send signals to backends so this capability was added to pg_ctl.
- Information schema improvements
- Add `--pwfile` option to initdb so the initial password can be set by GUI tools (Magnus)
- Detect locale/encoding mismatch in initdb (Peter)
- Add `register` command to pg_ctl to register Windows operating system service (Dave Page)

E.178.4.6. Data Type and Function Changes

- More complete support for composite types (row types) (Tom)

  Composite values can be used in many places where only scalar values worked before.
- Reject nonrectangular array values as erroneous (Joe)

  Formerly, `array_in` would silently build a surprising result.
- Overflow in integer arithmetic operations is now detected (Tom)

- The arithmetic operators associated with the single-byte `"char"` data type have been removed.

  Formerly, the parser would select these operators in many situations where an "unable to select an operator" error would be more appropriate, such as `null * null`. If you actually want to do arithmetic on a `"char"` column, you can cast it to integer explicitly.

- Syntax checking of array input values considerably tightened up (Joe)

  Junk that was previously allowed in odd places with odd results now causes an `ERROR`, for example, non-whitespace after the closing right brace.

- Empty-string array element values must now be written as `""`, rather than writing nothing (Joe)

  Formerly, both ways of writing an empty-string element value were allowed, but now a quoted empty string is required. The case where nothing at all appears will probably be considered to be a NULL element value in some future release.

- Array element trailing whitespace is now ignored (Joe)

  Formerly leading whitespace was ignored, but trailing whitespace between an element value and the delimiter or right brace was significant. Now trailing whitespace is also ignored.

- Emit array values with explicit array bounds when lower bound is not one (Joe)
- Accept `YYYY-monthname-DD` as a date string (Tom)
- Make `netmask` and `hostmask` functions return maximum-length mask length (Tom)
- Change factorial function to return `numeric` (Gavin)

  Returning `numeric` allows the factorial function to work for a wider range of input values.

- `to_char`/`to_date()` date conversion improvements (Kurt Roeckx, Fabien Coelho)
- Make `length()` disregard trailing spaces in `CHAR(n)` (Gavin)

  This change was made to improve consistency: trailing spaces are semantically insignificant in `CHAR(n)` data, so they should not be counted by `length()`.

- Warn about empty string being passed to `OID`/`float4`/`float8` data types (Neil)

  8.1 will throw an error instead.

- Allow leading or trailing whitespace in `int2`/`int4`/`int8`/`float4`/`float8` input routines (Neil)
- Better support for IEEE `Infinity` and `NaN` values in `float4`/`float8` (Neil)

  These should now work on all platforms that support IEEE-compliant floating point arithmetic.

- Add `week` option to `date_trunc()` (Robert Creager)
- Fix `to_char` for `1 BC` (previously it returned `1 AD`) (Bruce)
- Fix `date_part(year)` for BC dates (previously it returned one less than the correct year) (Bruce)
- Fix `date_part()` to return the proper millennium and century (Fabien Coelho)

  In previous versions, the century and millennium results had a wrong number and started in the wrong year, as compared to standard reckoning of such things.

- Add `ceiling()` as an alias for `ceil()`, and `power()` as an alias for `pow()` for standards compliance (Neil)
- Change `ln()`, `log()`, `power()`, and `sqrt()` to emit the correct `SQLSTATE` error codes for certain error conditions, as specified by SQL:2003 (Neil)
- Add `width_bucket()` function as defined by SQL:2003 (Neil)
- Add `generate_series()` functions to simplify working with numeric sets (Joe)

- Fix `upper/lower/initcap()` functions to work with multibyte encodings (Tom)
- Add boolean and bitwise integer `AND`/`OR` aggregates (Fabien Coelho)
- New session information functions to return network addresses for client and server (Sean Chittenden)
- Add function to determine the area of a closed path (Sean Chittenden)
- Add function to send cancel request to other backends (Magnus)
- Add `interval` plus `datetime` operators (Tom)

  The reverse ordering, `datetime` plus `interval`, was already supported, but both are required by the SQL standard.
- Casting an integer to `BIT(N)` selects the rightmost N bits of the integer (Tom)

  In prior releases, the leftmost N bits were selected, but this was deemed unhelpful, not to mention inconsistent with casting from bit to int.
- Require `CIDR` values to have all nonmasked bits be zero (Kevin Brintnall)

E.178.4.7. Server-Side Language Changes

- In `READ COMMITTED` serialization mode, volatile functions now see the results of concurrent transactions committed up to the beginning of each statement within the function, rather than up to the beginning of the interactive command that called the function.
- Functions declared `STABLE` or `IMMUTABLE` always use the snapshot of the calling query, and therefore do not see the effects of actions taken after the calling query starts, whether in their own transaction or other transactions. Such a function must be read-only, too, meaning that it cannot use any SQL commands other than `SELECT`. There is a considerable performance gain from declaring a function `STABLE` or `IMMUTABLE` rather than `VOLATILE`.
- Nondeferred `AFTER` triggers are now fired immediately after completion of the triggering query, rather than upon finishing the current interactive command. This makes a difference when the triggering query occurred within a function: the trigger is invoked before the function proceeds to its next operation. For example, if a function inserts a new row into a table, any nondeferred foreign key checks occur before proceeding with the function.
- Allow function parameters to be declared with names (Dennis Björklund)

  This allows better documentation of functions. Whether the names actually do anything depends on the specific function language being used.
- Allow PL/pgSQL parameter names to be referenced in the function (Dennis Björklund)

  This basically creates an automatic alias for each named parameter.
- Do minimal syntax checking of PL/pgSQL functions at creation time (Tom)

  This allows us to catch simple syntax errors sooner.
- More support for composite types (row and record variables) in PL/pgSQL

  For example, it now works to pass a rowtype variable to another function as a single variable.
- Default values for PL/pgSQL variables can now reference previously declared variables
- Improve parsing of PL/pgSQL FOR loops (Tom)

Parsing is now driven by presence of `".."` rather than data type of `FOR` variable. This makes no difference for correct functions, but should result in more understandable error messages when a mistake is made.

- Major overhaul of PL/Perl server-side language (Command Prompt, Andrew Dunstan)
- In PL/Tcl, SPI commands are now run in subtransactions. If an error occurs, the subtransaction is cleaned up and the error is reported as an ordinary Tcl error, which can be trapped with `catch`. Formerly, it was not possible to catch such errors.
- Accept `ELSEIF` in PL/pgSQL (Neil)

  Previously PL/pgSQL only allowed `ELSIF`, but many people are accustomed to spelling this keyword `ELSEIF`.

E.178.4.8. psql Changes

- Improve psql information display about database objects (Christopher)
- Allow psql to display group membership in `\du` and `\dg` (Markus Bertheau)
- Prevent psql `\dn` from showing temporary schemas (Bruce)
- Allow psql to handle tilde user expansion for file names (Zach Irmen)
- Allow psql to display fancy prompts, including color, via readline (Reece Hart, Chet Ramey)
- Make psql `\copy` match `COPY` command syntax fully (Tom)
- Show the location of syntax errors (Fabien Coelho, Tom)
- Add `CLUSTER` information to psql `\d` display (Bruce)
- Change psql `\copy stdin/stdout` to read from command input/output (Bruce)
- Add `pstdin`/`pstdout` to read from psql's `stdin`/`stdout` (Mark Feit)
- Add global psql configuration file, `psqlrc.sample` (Bruce)

  This allows a central file where global psql startup commands can be stored.
- Have psql `\d+` indicate if the table has an `OID` column (Neil)
- On Windows, use binary mode in psql when reading files so control-Z is not seen as end-of-file
- Have `\dn+` show permissions and description for schemas (Dennis Björklund)
- Improve tab completion support (Stefan Kaltenbrunn, Greg Sabino Mullane)
- Allow boolean settings to be set using upper or lower case (Michael Paesold)

E.178.4.9. pg_dump Changes

- Use dependency information to improve the reliability of pg_dump (Tom)

  This should solve the longstanding problems with related objects sometimes being dumped in the wrong order.
- Have pg_dump output objects in alphabetical order if possible (Tom)

  This should make it easier to identify changes between dump files.
- Allow pg_restore to ignore some SQL errors (Fabien Coelho)

This makes pg_restore's behavior similar to the results of feeding a pg_dump output script to psql. In most cases, ignoring errors and plowing ahead is the most useful thing to do. Also added was a pg_restore option to give the old behavior of exiting on an error.

- pg_restore `-l` display now includes objects' schema names
- New begin/end markers in pg_dump text output (Bruce)
- Add start/stop times for pg_dump/pg_dumpall in verbose mode (Bruce)
- Allow most pg_dump options in pg_dumpall (Christopher)
- Have pg_dump use `ALTER OWNER` rather than `SET SESSION AUTHORIZATION` by default (Christopher)

E.178.4.10. libpq Changes

- Make libpq's `SIGPIPE` handling thread-safe (Bruce)
- Add `PQmbdsplen()` which returns the display length of a character (Tatsuo)
- Add thread locking to SSL and Kerberos connections (Manfred Spraul)
- Allow `PQoidValue()`, `PQcmdTuples()`, and `PQoidStatus()` to work on `EXECUTE` commands (Neil)
- Add `PQserverVersion()` to provide more convenient access to the server version number (Greg Sabino Mullane)
- Add `PQprepare/PQsendPrepared()` functions to support preparing statements without necessarily specifying the data types of their parameters (Abhijit Menon-Sen)
- Many ECPG improvements, including `SET DESCRIPTOR` (Michael)

E.178.4.11. Source Code Changes

- Allow the database server to run natively on Windows (Claudio, Magnus, Andrew)
- Shell script commands converted to C versions for Windows support (Andrew)
- Create an extension makefile framework (Fabien Coelho, Peter)

  This simplifies the task of building extensions outside the original source tree.
- Support relocatable installations (Bruce)

  Directory paths for installed files (such as the `/share` directory) are now computed relative to the actual location of the executables, so that an installation tree can be moved to another place without reconfiguring and rebuilding.
- Use `--with-docdir` to choose installation location of documentation; also allow `--infodir` (Peter)
- Add `--without-docdir` to prevent installation of documentation (Peter)
- Upgrade to DocBook V4.2 SGML (Peter)
- New `PostgreSQL` CVS tag (Marc)

This was done to make it easier for organizations to manage their own copies of the PostgreSQL CVS repository. File version stamps from the master repository will not get munged by checking into or out of a copied repository.

- Clarify locking code (Manfred Koizar)
- Buffer manager cleanup (Neil)
- Decouple platform tests from CPU spinlock code (Bruce, Tom)
- Add inlined test-and-set code on PA-RISC for gcc (ViSolve, Tom)
- Improve i386 spinlock code (Manfred Spraul)
- Clean up spinlock assembly code to avoid warnings from newer gcc releases (Tom)
- Remove JDBC from source tree; now a separate project
- Remove the libpgtcl client interface; now a separate project
- More accurately estimate memory and file descriptor usage (Tom)
- Improvements to the Mac OS X startup scripts (Ray A.)
- New `fsync()` test program (Bruce)
- Major documentation improvements (Neil, Peter)
- Remove pg_encoding; not needed anymore
- Remove pg_id; not needed anymore
- Remove initlocation; not needed anymore
- Auto-detect thread flags (no more manual testing) (Bruce)
- Use Olson's public domain timezone library (Magnus)
- With threading enabled, use thread flags on Unixware for backend executables too (Bruce)

  Unixware cannot mix threaded and nonthreaded object files in the same executable, so everything must be compiled as threaded.
- psql now uses a flex-generated lexical analyzer to process command strings
- Reimplement the linked list data structure used throughout the backend (Neil)

  This improves performance by allowing list append and length operations to be more efficient.
- Allow dynamically loaded modules to create their own server configuration parameters (Thomas Hallgren)
- New Brazilian version of FAQ (Euler Taveira de Oliveira)
- Add French FAQ (Guillaume Lelarge)
- New pgevent for Windows logging
- Make libpq and ECPG build as proper shared libraries on OS X (Tom)

E.178.4.12. Contrib Changes

- Overhaul of `contrib/dblink` (Joe)
- `contrib/dbmirror` improvements (Steven Singer)
- New `contrib/xml2` (John Gray, Torchbox)
- Updated `contrib/mysql`

- New version of `contrib/btree_gist` (Teodor)
- New `contrib/trgm`, trigram matching for PostgreSQL (Teodor)
- Many `contrib/tsearch2` improvements (Teodor)
- Add double metaphone to `contrib/fuzzystrmatch` (Andrew)
- Allow `contrib/pg_autovacuum` to run as a Windows service (Dave Page)
- Add functions to `contrib/dbsize` (Andreas Pflug)
- Removed `contrib/pg_logger`: obsoleted by integrated logging subprocess
- Removed `contrib/rserv`: obsoleted by various separate projects

E.179. Release 7.4.30

Release Date: 2010-10-04

This release contains a variety of fixes from 7.4.29. For information about new features in the 7.4 major release, see Section E.209.

This is expected to be the last PostgreSQL release in the 7.4.X series. Users are encouraged to update to a newer release branch soon.

E.179.1. Migration to Version 7.4.30

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.26, see Section E.183.

E.179.2. Changes

- Use a separate interpreter for each calling SQL userid in PL/Perl and PL/Tcl (Tom Lane)

  This change prevents security problems that can be caused by subverting Perl or Tcl code that will be executed later in the same session under another SQL user identity (for example, within a `SECURITY DEFINER` function). Most scripting languages offer numerous ways that that might be done, such as redefining standard functions or operators called by the target function. Without this change, any SQL user with Perl or Tcl language usage rights can do essentially anything with the SQL privileges of the target function's owner.

  The cost of this change is that intentional communication among Perl and Tcl functions becomes more difficult. To provide an escape hatch, PL/PerlU and PL/TclU functions continue to use only one interpreter per session. This is not considered a security issue since all such functions execute at the trust level of a database superuser already.

  It is likely that third-party procedural languages that claim to offer trusted execution have similar security issues. We advise contacting the authors of any PL you are depending on for security-critical purposes.

Our thanks to Tim Bunce for pointing out this issue (CVE-2010-3433).

- Prevent possible crashes in `pg_get_expr()` by disallowing it from being called with an argument that is not one of the system catalog columns it's intended to be used with (Heikki Linnakangas, Tom Lane)
- Fix "cannot handle unplanned sub-select" error (Tom Lane)

  This occurred when a sub-select contains a join alias reference that expands into an expression containing another sub-select.
- Take care to fsync the contents of lockfiles (both `postmaster.pid` and the socket lockfile) while writing them (Tom Lane)

  This omission could result in corrupted lockfile contents if the machine crashes shortly after postmaster start. That could in turn prevent subsequent attempts to start the postmaster from succeeding, until the lockfile is manually removed.
- Improve `contrib/dblink`'s handling of tables containing dropped columns (Tom Lane)
- Fix connection leak after "duplicate connection name" errors in `contrib/dblink` (Itagaki Takahiro)
- Update build infrastructure and documentation to reflect the source code repository's move from CVS to Git (Magnus Hagander and others)

E.180. Release 7.4.29

Release Date: 2010-05-17

This release contains a variety of fixes from 7.4.28. For information about new features in the 7.4 major release, see Section E.209.

The PostgreSQL community will stop releasing updates for the 7.4.X release series in July 2010. Users are encouraged to update to a newer release branch soon.

E.180.1. Migration to Version 7.4.29

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.26, see Section E.183.

E.180.2. Changes

- Enforce restrictions in `plperl` using an opmask applied to the whole interpreter, instead of using `Safe.pm` (Tim Bunce, Andrew Dunstan)

  Recent developments have convinced us that `Safe.pm` is too insecure to rely on for making `plperl` trustable. This change removes use of `Safe.pm` altogether, in favor of using a separate interpreter with an opcode mask that is always applied. Pleasant side effects of the change include that it is now possible to use Perl's `strict` pragma in a natural way in `plperl`, and that Perl's `$a` and `$b`

variables work as expected in sort routines, and that function compilation is significantly faster. (CVE-2010-1169)

- Prevent PL/Tcl from executing untrustworthy code from `pltcl_modules` (Tom)

  PL/Tcl's feature for autoloading Tcl code from a database table could be exploited for trojan-horse attacks, because there was no restriction on who could create or insert into that table. This change disables the feature unless `pltcl_modules` is owned by a superuser. (However, the permissions on the table are not checked, so installations that really need a less-than-secure modules table can still grant suitable privileges to trusted non-superusers.) Also, prevent loading code into the unrestricted "normal" Tcl interpreter unless we are really going to execute a `pltclu` function. (CVE-2010-1170)

- Do not allow an unprivileged user to reset superuser-only parameter settings (Alvaro)

  Previously, if an unprivileged user ran `ALTER USER ... RESET ALL` for himself, or `ALTER DATABASE ... RESET ALL` for a database he owns, this would remove all special parameter settings for the user or database, even ones that are only supposed to be changeable by a superuser. Now, the `ALTER` will only remove the parameters that the user has permission to change.

- Avoid possible crash during backend shutdown if shutdown occurs when a `CONTEXT` addition would be made to log entries (Tom)

  In some cases the context-printing function would fail because the current transaction had already been rolled back when it came time to print a log message.

- Update pl/perl's `ppport.h` for modern Perl versions (Andrew)

- Fix assorted memory leaks in pl/python (Andreas Freund, Tom)

- Ensure that `contrib/pgstattuple` functions respond to cancel interrupts promptly (Tatsuhito Kasahara)

- Make server startup deal properly with the case that `shmget()` returns `EINVAL` for an existing shared memory segment (Tom)

  This behavior has been observed on BSD-derived kernels including OS X. It resulted in an entirely-misleading startup failure complaining that the shared memory request size was too large.

E.181. Release 7.4.28

Release Date: 2010-03-15

This release contains a variety of fixes from 7.4.27. For information about new features in the 7.4 major release, see Section E.209.

The PostgreSQL community will stop releasing updates for the 7.4.X release series in July 2010. Users are encouraged to update to a newer release branch soon.

E.181.1. Migration to Version 7.4.28

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.26, see Section E.183.

E.181.2. Changes

- Add new configuration parameter `ssl_renegotiation_limit` to control how often we do session key renegotiation for an SSL connection (Magnus)

  This can be set to zero to disable renegotiation completely, which may be required if a broken SSL library is used. In particular, some vendors are shipping stopgap patches for CVE-2009-3555 that cause renegotiation attempts to fail.

- Make `substring()` for `bit` types treat any negative length as meaning "all the rest of the string" (Tom)

  The previous coding treated only -1 that way, and would produce an invalid result value for other negative values, possibly leading to a crash (CVE-2010-0442).

- Fix some cases of pathologically slow regular expression matching (Tom)

- When reading `pg_hba.conf` and related files, do not treat `@something` as a file inclusion request if the `@` appears inside quote marks; also, never treat `@` by itself as a file inclusion request (Tom)

  This prevents erratic behavior if a role or database name starts with `@`. If you need to include a file whose path name contains spaces, you can still do so, but you must write `@"/path to/file"` rather than putting the quotes around the whole construct.

- Prevent infinite loop on some platforms if a directory is named as an inclusion target in `pg_hba.conf` and related files (Tom)

- Ensure PL/Tcl initializes the Tcl interpreter fully (Tom)

  The only known symptom of this oversight is that the Tcl `clock` command misbehaves if using Tcl 8.5 or later.

- Prevent crash in `contrib/dblink` when too many key columns are specified to a `dblink_build_sql_*` function (Rushabh Lathia, Joe Conway)

E.182. Release 7.4.27

Release Date: 2009-12-14

This release contains a variety of fixes from 7.4.26. For information about new features in the 7.4 major release, see Section E.209.

E.182.1. Migration to Version 7.4.27

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.26, see Section E.183.

E.182.2. Changes

- Protect against indirect security threats caused by index functions changing session-local state (Gurjeet Singh, Tom)

  This change prevents allegedly-immutable index functions from possibly subverting a superuser's session (CVE-2009-4136).

- Reject SSL certificates containing an embedded null byte in the common name (CN) field (Magnus)

  This prevents unintended matching of a certificate to a server or client name during SSL validation (CVE-2009-4034).

- Fix possible crash during backend-startup-time cache initialization (Tom)

- Prevent signals from interrupting `VACUUM` at unsafe times (Alvaro)

  This fix prevents a PANIC if a `VACUUM FULL` is canceled after it's already committed its tuple movements, as well as transient errors if a plain `VACUUM` is interrupted after having truncated the table.

- Fix possible crash due to integer overflow in hash table size calculation (Tom)

  This could occur with extremely large planner estimates for the size of a hashjoin's result.

- Fix very rare crash in `inet`/`cidr` comparisons (Chris Mikkelson)

- Fix PAM password processing to be more robust (Tom)

  The previous code is known to fail with the combination of the Linux `pam_krb5` PAM module with Microsoft Active Directory as the domain controller. It might have problems elsewhere too, since it was making unjustified assumptions about what arguments the PAM stack would pass to it.

- Make the postmaster ignore any `application_name` parameter in connection request packets, to improve compatibility with future libpq versions (Tom)

E.183. Release 7.4.26

Release Date: 2009-09-09

This release contains a variety of fixes from 7.4.25. For information about new features in the 7.4 major release, see Section E.209.

E.183.1. Migration to Version 7.4.26

A dump/restore is not required for those running 7.4.X. However, if you have any hash indexes on `interval` columns, you must `REINDEX` them after updating to 7.4.26. Also, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.183.2. Changes

- Disallow `RESET ROLE` and `RESET SESSION AUTHORIZATION` inside security-definer functions (Tom, Heikki)

  This covers a case that was missed in the previous patch that disallowed `SET ROLE` and `SET SESSION AUTHORIZATION` inside security-definer functions. (See CVE-2007-6600)
- Fix handling of sub-SELECTs appearing in the arguments of an outer-level aggregate function (Tom)
- Fix hash calculation for data type `interval` (Tom)

  This corrects wrong results for hash joins on interval values. It also changes the contents of hash indexes on interval columns. If you have any such indexes, you must `REINDEX` them after updating.
- Fix overflow for `INTERVAL 'x ms'` when *x* is more than 2 million and integer datetimes are in use (Alex Hunsaker)
- Fix calculation of distance between a point and a line segment (Tom)

  This led to incorrect results from a number of geometric operators.
- Fix `money` data type to work in locales where currency amounts have no fractional digits, e.g. Japan (Itagaki Takahiro)
- Properly round datetime input like `00:12:57.9999999999999999999999999999` (Tom)
- Fix poor choice of page split point in GiST R-tree operator classes (Teodor)
- Fix portability issues in plperl initialization (Andrew Dunstan)
- Improve robustness of libpq's code to recover from errors during `COPY FROM STDIN` (Tom)
- Avoid including conflicting readline and editline header files when both libraries are installed (Zdenek Kotala)

E.184. Release 7.4.25

Release Date: 2009-03-16

This release contains a variety of fixes from 7.4.24. For information about new features in the 7.4 major release, see Section E.209.

E.184.1. Migration to Version 7.4.25

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.184.2. Changes

- Prevent error recursion crashes when encoding conversion fails (Tom)

This change extends fixes made in the last two minor releases for related failure scenarios. The previous fixes were narrowly tailored for the original problem reports, but we have now recognized that *any* error thrown by an encoding conversion function could potentially lead to infinite recursion while trying to report the error. The solution therefore is to disable translation and encoding conversion and report the plain-ASCII form of any error message, if we find we have gotten into a recursive error reporting situation. (CVE-2009-0922)

- Disallow `CREATE CONVERSION` with the wrong encodings for the specified conversion function (Heikki)

  This prevents one possible scenario for encoding conversion failure. The previous change is a backstop to guard against other kinds of failures in the same area.

- Fix core dump when `to_char()` is given format codes that are inappropriate for the type of the data argument (Tom)

- Add `MUST` (Mauritius Island Summer Time) to the default list of known timezone abbreviations (Xavier Bugaud)

E.185. Release 7.4.24

Release Date: 2009-02-02

This release contains a variety of fixes from 7.4.23. For information about new features in the 7.4 major release, see Section E.209.

E.185.1. Migration to Version 7.4.24

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.185.2. Changes

- Improve handling of URLs in `headline()` function (Teodor)
- Improve handling of overlength headlines in `headline()` function (Teodor)
- Prevent possible Assert failure or misconversion if an encoding conversion is created with the wrong conversion function for the specified pair of encodings (Tom, Heikki)
- Avoid unnecessary locking of small tables in `VACUUM` (Heikki)
- Fix uninitialized variables in `contrib/tsearch2`'s `get_covers()` function (Teodor)
- Fix bug in `to_char()`'s handling of `TH` format codes (Andreas Scherbaum)
- Make all documentation reference `pgsql-bugs` and/or `pgsql-hackers` as appropriate, instead of the now-decommissioned `pgsql-ports` and `pgsql-patches` mailing lists (Tom)

E.186. Release 7.4.23

Release Date: 2008-11-03

This release contains a variety of fixes from 7.4.22. For information about new features in the 7.4 major release, see Section E.209.

E.186.1. Migration to Version 7.4.23

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.186.2. Changes

- Fix backend crash when the client encoding cannot represent a localized error message (Tom)

  We have addressed similar issues before, but it would still fail if the "character has no equivalent" message itself couldn't be converted. The fix is to disable localization and send the plain ASCII error message when we detect such a situation.
- Fix incorrect tsearch2 headline generation when single query item matches first word of text (Sushant Sinha)
- Fix improper display of fractional seconds in interval values when using a non-ISO datestyle in an `--enable-integer-datetimes` build (Ron Mayer)
- Ensure `SPI_getvalue` and `SPI_getbinval` behave correctly when the passed tuple and tuple descriptor have different numbers of columns (Tom)

  This situation is normal when a table has had columns added or removed, but these two functions didn't handle it properly. The only likely consequence is an incorrect error indication.
- Fix ecpg's parsing of `CREATE USER` (Michael)

E.187. Release 7.4.22

Release Date: 2008-09-22

This release contains a variety of fixes from 7.4.21. For information about new features in the 7.4 major release, see Section E.209.

E.187.1. Migration to Version 7.4.22

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.187.2. Changes

- Fix datetime input functions to correctly detect integer overflow when running on a 64-bit platform (Tom)
- Improve performance of writing very long log messages to syslog (Tom)
- Fix bug in backwards scanning of a cursor on a `SELECT DISTINCT ON` query (Tom)
- Fix planner to estimate that `GROUP BY` expressions yielding boolean results always result in two groups, regardless of the expressions' contents (Tom)

  This is very substantially more accurate than the regular `GROUP BY` estimate for certain boolean tests like *`col`* `IS NULL`.
- Improve pg_dump and pg_restore's error reporting after failure to send a SQL command (Tom)

E.188. Release 7.4.21

Release Date: 2008-06-12

This release contains one serious bug fix over 7.4.20. For information about new features in the 7.4 major release, see Section E.209.

E.188.1. Migration to Version 7.4.21

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.188.2. Changes

- Make `pg_get_ruledef()` parenthesize negative constants (Tom)

  Before this fix, a negative constant in a view or rule might be dumped as, say, `-42::integer`, which is subtly incorrect: it should be `(-42)::integer` due to operator precedence rules. Usually this would make little difference, but it could interact with another recent patch to cause PostgreSQL to reject what had been a valid `SELECT DISTINCT` view query. Since this could result in pg_dump output failing to reload, it is being treated as a high-priority fix. The only released versions in which dump output is actually incorrect are 8.3.1 and 8.2.7.

E.189. Release 7.4.20

Release Date: never released

This release contains a variety of fixes from 7.4.19. For information about new features in the 7.4 major release, see Section E.209.

E.189.1. Migration to Version 7.4.20

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.189.2. Changes

- Fix conversions between ISO-8859-5 and other encodings to handle Cyrillic "Yo" characters (`e` and `E` with two dots) (Sergey Burladyan)
- Fix a few datatype input functions that were allowing unused bytes in their results to contain uninitialized, unpredictable values (Tom)

  This could lead to failures in which two apparently identical literal values were not seen as equal, resulting in the parser complaining about unmatched `ORDER BY` and `DISTINCT` expressions.
- Fix a corner case in regular-expression substring matching (`substring(`*`string`* `from` *`pattern`*`)`) (Tom)

  The problem occurs when there is a match to the pattern overall but the user has specified a parenthesized subexpression and that subexpression hasn't got a match. An example is `substring('foo' from 'foo(bar)?')`. This should return NULL, since `(bar)` isn't matched, but it was mistakenly returning the whole-pattern match instead (ie, `foo`).
- Fix incorrect result from ecpg's `PGTYPEStimestamp_sub()` function (Michael)
- Fix `DatumGetBool` macro to not fail with gcc 4.3 (Tom)

  This problem affects "old style" (V0) C functions that return boolean. The fix is already in 8.3, but the need to back-patch it was not realized at the time.
- Fix longstanding `LISTEN`/`NOTIFY` race condition (Tom)

  In rare cases a session that had just executed a `LISTEN` might not get a notification, even though one would be expected because the concurrent transaction executing `NOTIFY` was observed to commit later.

  A side effect of the fix is that a transaction that has executed a not-yet-committed `LISTEN` command will not see any row in `pg_listener` for the `LISTEN`, should it choose to look; formerly it would have. This behavior was never documented one way or the other, but it is possible that some applications depend on the old behavior.
- Fix display of constant expressions in `ORDER BY` and `GROUP BY` (Tom)

  An explicitly casted constant would be shown incorrectly. This could for example lead to corruption of a view definition during dump and reload.
- Fix libpq to handle NOTICE messages correctly during COPY OUT (Tom)

  This failure has only been observed to occur when a user-defined datatype's output routine issues a NOTICE, but there is no guarantee it couldn't happen due to other causes.

E.190. Release 7.4.19

Release Date: 2008-01-07

This release contains a variety of fixes from 7.4.18, including fixes for significant security issues. For information about new features in the 7.4 major release, see Section E.209.

E.190.1. Migration to Version 7.4.19

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.190.2. Changes

- Prevent functions in indexes from executing with the privileges of the user running `VACUUM`, `ANALYZE`, etc (Tom)

  Functions used in index expressions and partial-index predicates are evaluated whenever a new table entry is made. It has long been understood that this poses a risk of trojan-horse code execution if one modifies a table owned by an untrustworthy user. (Note that triggers, defaults, check constraints, etc. pose the same type of risk.) But functions in indexes pose extra danger because they will be executed by routine maintenance operations such as `VACUUM FULL`, which are commonly performed automatically under a superuser account. For example, a nefarious user can execute code with superuser privileges by setting up a trojan-horse index definition and waiting for the next routine vacuum. The fix arranges for standard maintenance operations (including `VACUUM`, `ANALYZE`, `REINDEX`, and `CLUSTER`) to execute as the table owner rather than the calling user, using the same privilege-switching mechanism already used for `SECURITY DEFINER` functions. To prevent bypassing this security measure, execution of `SET SESSION AUTHORIZATION` and `SET ROLE` is now forbidden within a `SECURITY DEFINER` context. (CVE-2007-6600)

- Repair assorted bugs in the regular-expression package (Tom, Will Drewry)

  Suitably crafted regular-expression patterns could cause crashes, infinite or near-infinite looping, and/or massive memory consumption, all of which pose denial-of-service hazards for applications that accept regex search patterns from untrustworthy sources. (CVE-2007-4769, CVE-2007-4772, CVE-2007-6067)

- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

  The fix that appeared for this in 7.4.18 was incomplete, as it plugged the hole for only some `dblink` functions. (CVE-2007-6601, CVE-2007-3278)

- Fix planner failure in some cases of `WHERE false AND var IN (SELECT ...)` (Tom)

- Fix potential crash in `translate()` when using a multibyte database encoding (Tom)

- Fix PL/Python to not crash on long exception messages (Alvaro)

- ecpg parser fixes (Michael)

- Make `contrib/tablefunc`'s `crosstab()` handle NULL rowid as a category in its own right, rather than crashing (Joe)

- Fix `tsvector` and `tsquery` output routines to escape backslashes correctly (Teodor, Bruce)
- Fix crash of `to_tsvector()` on huge input strings (Teodor)
- Require a specific version of Autoconf to be used when re-generating the `configure` script (Peter)

  This affects developers and packagers only. The change was made to prevent accidental use of untested combinations of Autoconf and PostgreSQL versions. You can remove the version check if you really want to use a different Autoconf version, but it's your responsibility whether the result works or not.

E.191. Release 7.4.18

Release Date: 2007-09-17

This release contains fixes from 7.4.17. For information about new features in the 7.4 major release, see Section E.209.

E.191.1. Migration to Version 7.4.18

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.191.2. Changes

- Prevent index corruption when a transaction inserts rows and then aborts close to the end of a concurrent `VACUUM` on the same table (Tom)
- Make `CREATE DOMAIN ... DEFAULT NULL` work properly (Tom)
- Fix excessive logging of SSL error messages (Tom)
- Fix crash when `log_min_error_statement` logging runs out of memory (Tom)
- Prevent `CLUSTER` from failing due to attempting to process temporary tables of other sessions (Alvaro)
- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

E.192. Release 7.4.17

Release Date: 2007-04-23

This release contains fixes from 7.4.16, including a security fix. For information about new features in the 7.4 major release, see Section E.209.

E.192.1. Migration to Version 7.4.17

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.192.2. Changes

- Support explicit placement of the temporary-table schema within `search_path`, and disable searching it for functions and operators (Tom)

  This is needed to allow a security-definer function to set a truly secure value of `search_path`. Without it, an unprivileged SQL user can use temporary objects to execute code with the privileges of the security-definer function (CVE-2007-2138). See `CREATE FUNCTION` for more information.
- `/contrib/tsearch2` crash fixes (Teodor)
- Fix potential-data-corruption bug in how `VACUUM FULL` handles `UPDATE` chains (Tom, Pavan Deolasee)
- Fix PANIC during enlargement of a hash index (bug introduced in 7.4.15) (Tom)

E.193. Release 7.4.16

Release Date: 2007-02-05

This release contains a variety of fixes from 7.4.15, including a security fix. For information about new features in the 7.4 major release, see Section E.209.

E.193.1. Migration to Version 7.4.16

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.193.2. Changes

- Remove security vulnerability that allowed connected users to read backend memory (Tom)

  The vulnerability involves suppressing the normal check that a SQL function returns the data type it's declared to, or changing the data type of a table column used in a SQL function (CVE-2007-0555). This error can easily be exploited to cause a backend crash, and in principle might be used to read database content that the user should not be able to access.
- Fix rare bug wherein btree index page splits could fail due to choosing an infeasible split point (Heikki Linnakangas)
- Fix for rare Assert() crash triggered by `UNION` (Tom)

- Tighten security of multi-byte character processing for UTF8 sequences over three bytes long (Tom)

E.194. Release 7.4.15

Release Date: 2007-01-08

This release contains a variety of fixes from 7.4.14. For information about new features in the 7.4 major release, see Section E.209.

E.194.1. Migration to Version 7.4.15

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.194.2. Changes

- Improve handling of `getaddrinfo()` on AIX (Tom)

  This fixes a problem with starting the statistics collector, among other things.
- Fix "failed to re-find parent key" errors in `VACUUM` (Tom)
- Fix bugs affecting multi-gigabyte hash indexes (Tom)
- Fix error when constructing an `ARRAY[]` made up of multiple empty elements (Tom)
- `to_number()` and `to_char(numeric)` are now `STABLE`, not `IMMUTABLE`, for new initdb installs (Tom)

  This is because `lc_numeric` can potentially change the output of these functions.
- Improve index usage of regular expressions that use parentheses (Tom)

  This improves psql `\d` performance also.

E.195. Release 7.4.14

Release Date: 2006-10-16

This release contains a variety of fixes from 7.4.13. For information about new features in the 7.4 major release, see Section E.209.

E.195.1. Migration to Version 7.4.14

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.195.2. Changes

- Fix core dump when an untyped literal is taken as ANYARRAY
- Fix `string_to_array()` to handle overlapping matches for the separator string

  For example, `string_to_array('123xx456xxx789', 'xx')`.
- Fix corner cases in pattern matching for psql's `\d` commands
- Fix index-corrupting bugs in /contrib/ltree (Teodor)
- Fix backslash escaping in /contrib/dbmirror
- Adjust regression tests for recent changes in US DST laws

E.196. Release 7.4.13

Release Date: 2006-05-23

This release contains a variety of fixes from 7.4.12, including patches for extremely serious security issues. For information about new features in the 7.4 major release, see Section E.209.

E.196.1. Migration to Version 7.4.13

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

Full security against the SQL-injection attacks described in CVE-2006-2313 and CVE-2006-2314 might require changes in application code. If you have applications that embed untrustworthy strings into SQL commands, you should examine them as soon as possible to ensure that they are using recommended escaping techniques. In most cases, applications should be using subroutines provided by libraries or drivers (such as libpq's `PQescapeStringConn()`) to perform string escaping, rather than relying on *ad hoc* code to do it.

E.196.2. Changes

- Change the server to reject invalidly-encoded multibyte characters in all cases (Tatsuo, Tom)

  While PostgreSQL has been moving in this direction for some time, the checks are now applied uniformly to all encodings and all textual input, and are now always errors not merely warnings. This change defends against SQL-injection attacks of the type described in CVE-2006-2313.
- Reject unsafe uses of `\'` in string literals

As a server-side defense against SQL-injection attacks of the type described in CVE-2006-2314, the server now only accepts `''` and not `\'` as a representation of ASCII single quote in SQL string literals. By default, `\'` is rejected only when `client_encoding` is set to a client-only encoding (SJIS, BIG5, GBK, GB18030, or UHC), which is the scenario in which SQL injection is possible. A new configuration parameter `backslash_quote` is available to adjust this behavior when needed. Note that full security against CVE-2006-2314 might require client-side changes; the purpose of `backslash_quote` is in part to make it obvious that insecure clients are insecure.

- Modify libpq's string-escaping routines to be aware of encoding considerations and `standard_conforming_strings`

  This fixes libpq-using applications for the security issues described in CVE-2006-2313 and CVE-2006-2314, and also future-proofs them against the planned changeover to SQL-standard string literal syntax. Applications that use multiple PostgreSQL connections concurrently should migrate to `PQescapeStringConn()` and `PQescapeByteaConn()` to ensure that escaping is done correctly for the settings in use in each database connection. Applications that do string escaping "by hand" should be modified to rely on library routines instead.

- Fix some incorrect encoding conversion functions

  `win1251_to_iso`, `alt_to_iso`, `euc_tw_to_big5`, `euc_tw_to_mic`, `mic_to_euc_tw` were all broken to varying extents.

- Clean up stray remaining uses of `\'` in strings (Bruce, Jan)
- Fix bug that sometimes caused OR'd index scans to miss rows they should have returned
- Fix WAL replay for case where a btree index has been truncated
- Fix `SIMILAR TO` for patterns involving `|` (Tom)
- Fix server to use custom DH SSL parameters correctly (Michael Fuhr)
- Fix for Bonjour on Intel Macs (Ashley Clark)
- Fix various minor memory leaks

E.197. Release 7.4.12

Release Date: 2006-02-14

This release contains a variety of fixes from 7.4.11. For information about new features in the 7.4 major release, see Section E.209.

E.197.1. Migration to Version 7.4.12

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.11, see Section E.198.

E.197.2. Changes

- Fix potential crash in `SET SESSION AUTHORIZATION` (CVE-2006-0553)

An unprivileged user could crash the server process, resulting in momentary denial of service to other users, if the server has been compiled with Asserts enabled (which is not the default). Thanks to Akio Ishida for reporting this problem.

- Fix bug with row visibility logic in self-inserted rows (Tom)

  Under rare circumstances a row inserted by the current command could be seen as already valid, when it should not be. Repairs bug created in 7.4.9 and 7.3.11 releases.

- Fix race condition that could lead to "file already exists" errors during pg_clog file creation (Tom)
- Properly check `DOMAIN` constraints for `UNKNOWN` parameters in prepared statements (Neil)
- Fix to allow restoring dumps that have cross-schema references to custom operators (Tom)
- Portability fix for testing presence of `finite` and `isinf` during configure (Tom)

E.198. Release 7.4.11

Release Date: 2006-01-09

This release contains a variety of fixes from 7.4.10. For information about new features in the 7.4 major release, see Section E.209.

E.198.1. Migration to Version 7.4.11

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.8, see Section E.201. Also, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the locale or plperl issues described below.

E.198.2. Changes

- Fix for protocol-level Describe messages issued outside a transaction or in a failed transaction (Tom)
- Fix character string comparison for locales that consider different character combinations as equal, such as Hungarian (Tom)

  This might require `REINDEX` to fix existing indexes on textual columns.

- Set locale environment variables during postmaster startup to ensure that plperl won't change the locale later

  This fixes a problem that occurred if the postmaster was started with environment variables specifying a different locale than what initdb had been told. Under these conditions, any use of plperl was likely to lead to corrupt indexes. You might need `REINDEX` to fix existing indexes on textual columns if this has happened to you.

- Fix longstanding bug in strpos() and regular expression handling in certain rarely used Asian multibyte character sets (Tatsuo)

- Fix bug in `/contrib/pgcrypto` gen_salt, which caused it not to use all available salt space for MD5 and XDES algorithms (Marko Kreen, Solar Designer)

  Salts for Blowfish and standard DES are unaffected.

- Fix `/contrib/dblink` to throw an error, rather than crashing, when the number of columns specified is different from what's actually returned by the query (Joe)

E.199. Release 7.4.10

Release Date: 2005-12-12

This release contains a variety of fixes from 7.4.9. For information about new features in the 7.4 major release, see Section E.209.

E.199.1. Migration to Version 7.4.10

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.8, see Section E.201.

E.199.2. Changes

- Fix race condition in transaction log management

  There was a narrow window in which an I/O operation could be initiated for the wrong page, leading to an Assert failure or data corruption.

- Prevent failure if client sends Bind protocol message when current transaction is already aborted
- `/contrib/ltree` fixes (Teodor)
- AIX and HPUX compile fixes (Tom)
- Fix longstanding planning error for outer joins

  This bug sometimes caused a bogus error "RIGHT JOIN is only supported with merge-joinable join conditions".

- Prevent core dump in pg_autovacuum when a table has been dropped

E.200. Release 7.4.9

Release Date: 2005-10-04

This release contains a variety of fixes from 7.4.8. For information about new features in the 7.4 major release, see Section E.209.

E.200.1. Migration to Version 7.4.9

A dump/restore is not required for those running 7.4.X. However, if you are upgrading from a version earlier than 7.4.8, see Section E.201.

E.200.2. Changes

- Fix error that allowed `VACUUM` to remove `ctid` chains too soon, and add more checking in code that follows `ctid` links

  This fixes a long-standing problem that could cause crashes in very rare circumstances.

- Fix `CHAR()` to properly pad spaces to the specified length when using a multiple-byte character set (Yoshiyuki Asaba)

  In prior releases, the padding of `CHAR()` was incorrect because it only padded to the specified number of bytes without considering how many characters were stored.

- Fix the sense of the test for read-only transaction in `COPY`

  The code formerly prohibited `COPY TO`, where it should prohibit `COPY FROM`.

- Fix planning problem with outer-join ON clauses that reference only the inner-side relation
- Further fixes for `x FULL JOIN y ON true` corner cases
- Make `array_in` and `array_recv` more paranoid about validating their OID parameter
- Fix missing rows in queries like `UPDATE a=... WHERE a...` with GiST index on column `a`
- Improve robustness of datetime parsing
- Improve checking for partially-written WAL pages
- Improve robustness of signal handling when SSL is enabled
- Don't try to open more than `max_files_per_process` files during postmaster startup
- Various memory leakage fixes
- Various portability improvements
- Fix PL/pgSQL to handle `var := var` correctly when the variable is of pass-by-reference type
- Update `contrib/tsearch2` to use current Snowball code

E.201. Release 7.4.8

Release Date: 2005-05-09

This release contains a variety of fixes from 7.4.7, including several security-related issues. For information about new features in the 7.4 major release, see Section E.209.

E.201.1. Migration to Version 7.4.8

A dump/restore is not required for those running 7.4.X. However, it is one possible way of handling two significant security problems that have been found in the initial contents of 7.4.X system catalogs. A dump/initdb/reload sequence using 7.4.8's initdb will automatically correct these problems.

The larger security problem is that the built-in character set encoding conversion functions can be invoked from SQL commands by unprivileged users, but the functions were not designed for such use and are not secure against malicious choices of arguments. The fix involves changing the declared parameter list of these functions so that they can no longer be invoked from SQL commands. (This does not affect their normal use by the encoding conversion machinery.)

The lesser problem is that the `contrib/tsearch2` module creates several functions that are misdeclared to return `internal` when they do not accept `internal` arguments. This breaks type safety for all functions using `internal` arguments.

It is strongly recommended that all installations repair these errors, either by initdb or by following the manual repair procedures given below. The errors at least allow unprivileged database users to crash their server process, and might allow unprivileged users to gain the privileges of a database superuser.

If you wish not to do an initdb, perform the following procedures instead. As the database superuser, do:

```
BEGIN;
UPDATE pg_proc SET proargtypes[3] = 'internal'::regtype
WHERE pronamespace = 11 AND pronargs = 5
     AND proargtypes[2] = 'cstring'::regtype;
-- The command should report having updated 90 rows;
-- if not, rollback and investigate instead of committing!
COMMIT;
```

Next, if you have installed `contrib/tsearch2`, do:

```
BEGIN;
UPDATE pg_proc SET proargtypes[0] = 'internal'::regtype
WHERE oid IN (
   'dex_init(text)'::regprocedure,
   'snb_en_init(text)'::regprocedure,
   'snb_ru_init(text)'::regprocedure,
   'spell_init(text)'::regprocedure,
   'syn_init(text)'::regprocedure
);
-- The command should report having updated 5 rows;
-- if not, rollback and investigate instead of committing!
COMMIT;
```

If this command fails with a message like "function "dex_init(text)" does not exist", then either `tsearch2` is not installed in this database, or you already did the update.

The above procedures must be carried out in *each* database of an installation, including `template1`, and ideally including `template0` as well. If you do not fix the template databases then any subsequently created databases will contain the same errors. `template1` can be fixed in the same way as any other database, but fixing `template0` requires additional steps. First, from any database issue:

```
UPDATE pg_database SET datallowconn = true WHERE datname = 'template0';
```

Next connect to `template0` and perform the above repair procedures. Finally, do:

```
-- re-freeze template0:
VACUUM FREEZE;
-- and protect it against future alterations:
UPDATE pg_database SET datallowconn = false WHERE datname = 'template0';
```

E.201.2. Changes

- Change encoding function signature to prevent misuse
- Change `contrib/tsearch2` to avoid unsafe use of `INTERNAL` function results
- Repair ancient race condition that allowed a transaction to be seen as committed for some purposes (eg SELECT FOR UPDATE) slightly sooner than for other purposes

  This is an extremely serious bug since it could lead to apparent data inconsistencies being briefly visible to applications.
- Repair race condition between relation extension and VACUUM

  This could theoretically have caused loss of a page's worth of freshly-inserted data, although the scenario seems of very low probability. There are no known cases of it having caused more than an Assert failure.
- Fix comparisons of `TIME WITH TIME ZONE` values

  The comparison code was wrong in the case where the `--enable-integer-datetimes` configuration switch had been used. NOTE: if you have an index on a `TIME WITH TIME ZONE` column, it will need to be `REINDEX`ed after installing this update, because the fix corrects the sort order of column values.
- Fix `EXTRACT(EPOCH)` for `TIME WITH TIME ZONE` values
- Fix mis-display of negative fractional seconds in `INTERVAL` values

  This error only occurred when the `--enable-integer-datetimes` configuration switch had been used.
- Ensure operations done during backend shutdown are counted by statistics collector

  This is expected to resolve reports of pg_autovacuum not vacuuming the system catalogs often enough — it was not being told about catalog deletions caused by temporary table removal during backend exit.
- Additional buffer overrun checks in plpgsql (Neil)
- Fix pg_dump to dump trigger names containing `%` correctly (Neil)
- Fix `contrib/pgcrypto` for newer OpenSSL builds (Marko Kreen)
- Still more 64-bit fixes for `contrib/intagg`
- Prevent incorrect optimization of functions returning `RECORD`
- Prevent `to_char(interval)` from dumping core for month-related formats
- Prevent crash on `COALESCE(NULL,NULL)`
- Fix `array_map` to call PL functions correctly
- Fix permission checking in `ALTER DATABASE RENAME`
- Fix `ALTER LANGUAGE RENAME`

- Make `RemoveFromWaitQueue` clean up after itself

  This fixes a lock management error that would only be visible if a transaction was kicked out of a wait for a lock (typically by query cancel) and then the holder of the lock released it within a very narrow window.

- Fix problem with untyped parameter appearing in `INSERT ... SELECT`
- Fix `CLUSTER` failure after `ALTER TABLE SET WITHOUT OIDS`

E.202. Release 7.4.7

Release Date: 2005-01-31

This release contains a variety of fixes from 7.4.6, including several security-related issues. For information about new features in the 7.4 major release, see Section E.209.

E.202.1. Migration to Version 7.4.7

A dump/restore is not required for those running 7.4.X.

E.202.2. Changes

- Disallow `LOAD` to non-superusers

  On platforms that will automatically execute initialization functions of a shared library (this includes at least Windows and ELF-based Unixen), `LOAD` can be used to make the server execute arbitrary code. Thanks to NGS Software for reporting this.

- Check that creator of an aggregate function has the right to execute the specified transition functions

  This oversight made it possible to bypass denial of EXECUTE permission on a function.

- Fix security and 64-bit issues in contrib/intagg
- Add needed STRICT marking to some contrib functions (Kris Jurka)
- Avoid buffer overrun when plpgsql cursor declaration has too many parameters (Neil)
- Fix planning error for FULL and RIGHT outer joins

  The result of the join was mistakenly supposed to be sorted the same as the left input. This could not only deliver mis-sorted output to the user, but in case of nested merge joins could give outright wrong answers.

- Fix plperl for quote marks in tuple fields
- Fix display of negative intervals in SQL and GERMAN datestyles
- Make age(timestamptz) do calculation in local timezone not GMT

E.203. Release 7.4.6

Release Date: 2004-10-22

This release contains a variety of fixes from 7.4.5. For information about new features in the 7.4 major release, see Section E.209.

E.203.1. Migration to Version 7.4.6

A dump/restore is not required for those running 7.4.X.

E.203.2. Changes

- Repair possible failure to update hint bits on disk

  Under rare circumstances this oversight could lead to "could not access transaction status" failures, which qualifies it as a potential-data-loss bug.

- Ensure that hashed outer join does not miss tuples

  Very large left joins using a hash join plan could fail to output unmatched left-side rows given just the right data distribution.

- Disallow running pg_ctl as root

  This is to guard against any possible security issues.

- Avoid using temp files in `/tmp` in `make_oidjoins_check`

  This has been reported as a security issue, though it's hardly worthy of concern since there is no reason for non-developers to use this script anyway.

- Prevent forced backend shutdown from re-emitting prior command result

  In rare cases, a client might think that its last command had succeeded when it really had been aborted by forced database shutdown.

- Repair bug in `pg_stat_get_backend_idset`

  This could lead to misbehavior in some of the system-statistics views.

- Fix small memory leak in postmaster

- Fix "expected both swapped tables to have TOAST tables" bug

  This could arise in cases such as CLUSTER after ALTER TABLE DROP COLUMN.

- Prevent `pg_ctl restart` from adding `-D` multiple times

- Fix problem with NULL values in GiST indexes

- `::` is no longer interpreted as a variable in an ECPG prepare statement

E.204. Release 7.4.5

Release Date: 2004-08-18

This release contains one serious bug fix over 7.4.4. For information about new features in the 7.4 major release, see Section E.209.

E.204.1. Migration to Version 7.4.5

A dump/restore is not required for those running 7.4.X.

E.204.2. Changes

- Repair possible crash during concurrent B-tree index insertions

  This patch fixes a rare case in which concurrent insertions into a B-tree index could result in a server panic. No permanent damage would result, but it's still worth a re-release. The bug does not exist in pre-7.4 releases.

E.205. Release 7.4.4

Release Date: 2004-08-16

This release contains a variety of fixes from 7.4.3. For information about new features in the 7.4 major release, see Section E.209.

E.205.1. Migration to Version 7.4.4

A dump/restore is not required for those running 7.4.X.

E.205.2. Changes

- Prevent possible loss of committed transactions during crash

  Due to insufficient interlocking between transaction commit and checkpointing, it was possible for transactions committed just before the most recent checkpoint to be lost, in whole or in part, following a database crash and restart. This is a serious bug that has existed since PostgreSQL 7.1.
- Check HAVING restriction before evaluating result list of an aggregate plan
- Avoid crash when session's current user ID is deleted
- Fix hashed crosstab for zero-rows case (Joe)

- Force cache update after renaming a column in a foreign key
- Pretty-print UNION queries correctly
- Make psql handle `\r\n` newlines properly in COPY IN
- pg_dump handled ACLs with grant options incorrectly
- Fix thread support for OS X and Solaris
- Updated JDBC driver (build 215) with various fixes
- ECPG fixes
- Translation updates (various contributors)

E.206. Release 7.4.3

Release Date: 2004-06-14

This release contains a variety of fixes from 7.4.2. For information about new features in the 7.4 major release, see Section E.209.

E.206.1. Migration to Version 7.4.3

A dump/restore is not required for those running 7.4.X.

E.206.2. Changes

- Fix temporary memory leak when using non-hashed aggregates (Tom)
- ECPG fixes, including some for Informix compatibility (Michael)
- Fixes for compiling with thread-safety, particularly Solaris (Bruce)
- Fix error in COPY IN termination when using the old network protocol (ljb)
- Several important fixes in pg_autovacuum, including fixes for large tables, unsigned oids, stability, temp tables, and debug mode (Matthew T. O'Connor)
- Fix problem with reading tar-format dumps on NetBSD and BSD/OS (Bruce)
- Several JDBC fixes
- Fix ALTER SEQUENCE RESTART where last_value equals the restart value (Tom)
- Repair failure to recalculate nested sub-selects (Tom)
- Fix problems with non-constant expressions in LIMIT/OFFSET
- Support FULL JOIN with no join clause, such as X FULL JOIN Y ON TRUE (Tom)
- Fix another zero-column table bug (Tom)
- Improve handling of non-qualified identifiers in GROUP BY clauses in sub-selects (Tom)

Select-list aliases within the sub-select will now take precedence over names from outer query levels.

- Do not generate "NATURAL CROSS JOIN" when decompiling rules (Tom)
- Add checks for invalid field length in binary COPY (Tom)

  This fixes a difficult-to-exploit security hole.
- Avoid locking conflict between `ANALYZE` and `LISTEN`/`NOTIFY`
- Numerous translation updates (various contributors)

E.207. Release 7.4.2

Release Date: 2004-03-08

This release contains a variety of fixes from 7.4.1. For information about new features in the 7.4 major release, see Section E.209.

E.207.1. Migration to Version 7.4.2

A dump/restore is not required for those running 7.4.X. However, it might be advisable as the easiest method of incorporating fixes for two errors that have been found in the initial contents of 7.4.X system catalogs. A dump/initdb/reload sequence using 7.4.2's initdb will automatically correct these problems.

The more severe of the two errors is that data type `anyarray` has the wrong alignment label; this is a problem because the `pg_statistic` system catalog uses `anyarray` columns. The mislabeling can cause planner misestimations and even crashes when planning queries that involve `WHERE` clauses on double-aligned columns (such as `float8` and `timestamp`). It is strongly recommended that all installations repair this error, either by initdb or by following the manual repair procedure given below.

The lesser error is that the system view `pg_settings` ought to be marked as having public update access, to allow `UPDATE pg_settings` to be used as a substitute for `SET`. This can also be fixed either by initdb or manually, but it is not necessary to fix unless you want to use `UPDATE pg_settings`.

If you wish not to do an initdb, the following procedure will work for fixing `pg_statistic`. As the database superuser, do:

```
-- clear out old data in pg_statistic:
DELETE FROM pg_statistic;
VACUUM pg_statistic;
-- this should update 1 row:
UPDATE pg_type SET typalign = 'd' WHERE oid = 2277;
-- this should update 6 rows:
UPDATE pg_attribute SET attalign = 'd' WHERE atttypid = 2277;
--
-- At this point you MUST start a fresh backend to avoid a crash!
--
-- repopulate pg_statistic:
ANALYZE;
```

This can be done in a live database, but beware that all backends running in the altered database must be restarted before it is safe to repopulate `pg_statistic`.

To repair the `pg_settings` error, simply do:

```
GRANT SELECT, UPDATE ON pg_settings TO PUBLIC;
```

The above procedures must be carried out in *each* database of an installation, including `template1`, and ideally including `template0` as well. If you do not fix the template databases then any subsequently created databases will contain the same errors. `template1` can be fixed in the same way as any other database, but fixing `template0` requires additional steps. First, from any database issue:

```
UPDATE pg_database SET datallowconn = true WHERE datname = 'template0';
```

Next connect to `template0` and perform the above repair procedures. Finally, do:

```
-- re-freeze template0:
VACUUM FREEZE;
-- and protect it against future alterations:
UPDATE pg_database SET datallowconn = false WHERE datname = 'template0';
```

E.207.2. Changes

Release 7.4.2 incorporates all the fixes included in release 7.3.6, plus the following fixes:

- Fix `pg_statistics` alignment bug that could crash optimizer

  See above for details about this problem.
- Allow non-super users to update `pg_settings`
- Fix several optimizer bugs, most of which led to "variable not found in subplan target lists" errors
- Avoid out-of-memory failure during startup of large multiple index scan
- Fix multibyte problem that could lead to "out of memory" error during `COPY IN`
- Fix problems with `SELECT INTO` / `CREATE TABLE AS` from tables without OIDs
- Fix problems with `alter_table` regression test during parallel testing
- Fix problems with hitting open file limit, especially on OS X (Tom)
- Partial fix for Turkish-locale issues

  initdb will succeed now in Turkish locale, but there are still some inconveniences associated with the `i/I` problem.
- Make pg_dump set client encoding on restore
- Other minor pg_dump fixes
- Allow ecpg to again use C keywords as column names (Michael)
- Added ecpg `WHENEVER NOT_FOUND` to `SELECT/INSERT/UPDATE/DELETE` (Michael)
- Fix ecpg crash for queries calling set-returning functions (Michael)
- Various other ecpg fixes (Michael)

- Fixes for Borland compiler
- Thread build improvements (Bruce)
- Various other build fixes
- Various JDBC fixes

E.208. Release 7.4.1

Release Date: 2003-12-22

This release contains a variety of fixes from 7.4. For information about new features in the 7.4 major release, see Section E.209.

E.208.1. Migration to Version 7.4.1

A dump/restore is *not* required for those running 7.4.

If you want to install the fixes in the information schema you need to reload it into the database. This is either accomplished by initializing a new cluster by running `initdb`, or by running the following sequence of SQL commands in each database (ideally including `template1`) as a superuser in psql, after installing the new release:

```
DROP SCHEMA information_schema CASCADE;
\i /usr/local/pgsql/share/information_schema.sql
```

Substitute your installation path in the second command.

E.208.2. Changes

- Fixed bug in `CREATE SCHEMA` parsing in ECPG (Michael)
- Fix compile error when `--enable-thread-safety` and `--with-perl` are used together (Peter)
- Fix for subqueries that used hash joins (Tom)

  Certain subqueries that used hash joins would crash because of improperly shared structures.
- Fix free space map compaction bug (Tom)

  This fixes a bug where compaction of the free space map could lead to a database server shutdown.
- Fix for Borland compiler build of libpq (Bruce)
- Fix `netmask()` and `hostmask()` to return the maximum-length masklen (Tom)

  Fix these functions to return values consistent with pre-7.4 releases.
- Several `contrib/pg_autovacuum` fixes

  Fixes include improper variable initialization, missing vacuum after `TRUNCATE`, and duration computation overflow for long vacuums.
- Allow compile of `contrib/cube` under Cygwin (Jason Tishler)

- Fix Solaris use of password file when no passwords are defined (Tom)

  Fix crash on Solaris caused by use of any type of password authentication when no passwords were defined.
- JDBC fix for thread problems, other fixes
- Fix for `bytea` index lookups (Joe)
- Fix information schema for bit data types (Peter)
- Force zero_damaged_pages to be on during recovery from WAL
- Prevent some obscure cases of "variable not in subplan target lists"
- Make `PQescapeBytea` and `byteaout` consistent with each other (Joe)
- Escape `bytea` output for bytes > 0x7e(Joe)

  If different client encodings are used for `bytea` output and input, it is possible for `bytea` values to be corrupted by the differing encodings. This fix escapes all bytes that might be affected.
- Added missing `SPI_finish()` calls to dblink's `get_tuple_of_interest()` (Joe)
- New Czech FAQ
- Fix information schema view `constraint_column_usage` for foreign keys (Peter)
- ECPG fixes (Michael)
- Fix bug with multiple `IN` subqueries and joins in the subqueries (Tom)
- Allow `COUNT('x')` to work (Tom)
- Install ECPG include files for Informix compatibility into separate directory (Peter)

  Some names of ECPG include files for Informix compatibility conflicted with operating system include files. By installing them in their own directory, name conflicts have been reduced.
- Fix SSL memory leak (Neil)

  This release fixes a bug in 7.4 where SSL didn't free all memory it allocated.
- Prevent `pg_service.conf` from using service name as default dbname (Bruce)
- Fix local ident authentication on FreeBSD (Tom)

E.209. Release 7.4

Release Date: 2003-11-17

E.209.1. Overview

Major changes in this release:

`IN` / `NOT IN` subqueries are now much more efficient

In previous releases, `IN`/`NOT IN` subqueries were joined to the upper query by sequentially scanning the subquery looking for a match. The 7.4 code uses the same sophisticated techniques used by ordinary joins and so is much faster. An `IN` will now usually be as fast as or faster than an

equivalent `EXISTS` subquery; this reverses the conventional wisdom that applied to previous releases.

Improved `GROUP BY` processing by using hash buckets

In previous releases, rows to be grouped had to be sorted first. The 7.4 code can do `GROUP BY` without sorting, by accumulating results into a hash table with one entry per group. It will still use the sort technique, however, if the hash table is estimated to be too large to fit in `sort_mem`.

New multikey hash join capability

In previous releases, hash joins could only occur on single keys. This release allows multicolumn hash joins.

Queries using the explicit `JOIN` syntax are now better optimized

Prior releases evaluated queries using the explicit `JOIN` syntax only in the order implied by the syntax. 7.4 allows full optimization of these queries, meaning the optimizer considers all possible join orderings and chooses the most efficient. Outer joins, however, must still follow the declared ordering.

Faster and more powerful regular expression code

The entire regular expression module has been replaced with a new version by Henry Spencer, originally written for Tcl. The code greatly improves performance and supports several flavors of regular expressions.

Function-inlining for simple SQL functions

Simple SQL functions can now be inlined by including their SQL in the main query. This improves performance by eliminating per-call overhead. That means simple SQL functions now behave like macros.

Full support for IPv6 connections and IPv6 address data types

Previous releases allowed only IPv4 connections, and the IP data types only supported IPv4 addresses. This release adds full IPv6 support in both of these areas.

Major improvements in SSL performance and reliability

Several people very familiar with the SSL API have overhauled our SSL code to improve SSL key negotiation and error recovery.

Make free space map efficiently reuse empty index pages, and other free space management improvements

In previous releases, B-tree index pages that were left empty because of deleted rows could only be reused by rows with index values similar to the rows originally indexed on that page. In 7.4, `VACUUM` records empty index pages and allows them to be reused for any future index rows.

SQL-standard information schema

The information schema provides a standardized and stable way to access information about the schema objects defined in a database.

Cursors conform more closely to the SQL standard

The commands `FETCH` and `MOVE` have been overhauled to conform more closely to the SQL standard.

Cursors can exist outside transactions

These cursors are also called holdable cursors.

New client-to-server protocol

The new protocol adds error codes, more status information, faster startup, better support for binary data transmission, parameter values separated from SQL commands, prepared statements available at the protocol level, and cleaner recovery from COPY failures. The older protocol is still supported by both server and clients.

libpq and ECPG applications are now fully thread-safe

While previous libpq releases already supported threads, this release improves thread safety by fixing some non-thread-safe code that was used during database connection startup. The configure option --enable-thread-safety must be used to enable this feature.

New version of full-text indexing

A new full-text indexing suite is available in contrib/tsearch2.

New autovacuum tool

The new autovacuum tool in contrib/autovacuum monitors the database statistics tables for INSERT/UPDATE/DELETE activity and automatically vacuums tables when needed.

Array handling has been improved and moved into the server core

Many array limitations have been removed, and arrays behave more like fully-supported data types.

E.209.2. Migration to Version 7.4

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

- The server-side autocommit setting was removed and reimplemented in client applications and languages. Server-side autocommit was causing too many problems with languages and applications that wanted to control their own autocommit behavior, so autocommit was removed from the server and added to individual client APIs as appropriate.
- Error message wording has changed substantially in this release. Significant effort was invested to make the messages more consistent and user-oriented. If your applications try to detect different error conditions by parsing the error message, you are strongly encouraged to use the new error code facility instead.
- Inner joins using the explicit JOIN syntax might behave differently because they are now better optimized.
- A number of server configuration parameters have been renamed for clarity, primarily those related to logging.
- FETCH 0 or MOVE 0 now does nothing. In prior releases, FETCH 0 would fetch all remaining rows, and MOVE 0 would move to the end of the cursor.
- FETCH and MOVE now return the actual number of rows fetched/moved, or zero if at the beginning/end of the cursor. Prior releases would return the row count passed to the command, not the number of rows actually fetched or moved.
- COPY now can process files that use carriage-return or carriage-return/line-feed end-of-line sequences. Literal carriage-returns and line-feeds are no longer accepted in data values; use \r and \n instead.

- Trailing spaces are now trimmed when converting from type `char(n)` to `varchar(n)` or `text`. This is what most people always expected to happen anyway.
- The data type `float(p)` now measures *p* in binary digits, not decimal digits. The new behavior follows the SQL standard.
- Ambiguous date values now must match the ordering specified by the `datestyle` setting. In prior releases, a date specification of `10/20/03` was interpreted as a date in October even if `datestyle` specified that the day should be first. 7.4 will throw an error if a date specification is invalid for the current setting of `datestyle`.
- The functions `oidrand`, `oidsrand`, and `userfntest` have been removed. These functions were determined to be no longer useful.
- String literals specifying time-varying date/time values, such as `'now'` or `'today'` will no longer work as expected in column default expressions; they now cause the time of the table creation to be the default, not the time of the insertion. Functions such as `now()`, `current_timestamp`, or `current_date` should be used instead.

  In previous releases, there was special code so that strings such as `'now'` were interpreted at `INSERT` time and not at table creation time, but this work around didn't cover all cases. Release 7.4 now requires that defaults be defined properly using functions such as `now()` or `current_timestamp`. These will work in all situations.
- The dollar sign (`$`) is no longer allowed in operator names. It can instead be a non-first character in identifiers. This was done to improve compatibility with other database systems, and to avoid syntax problems when parameter placeholders (`$n`) are written adjacent to operators.

E.209.3. Changes

Below you will find a detailed account of the changes between release 7.4 and the previous major release.

E.209.3.1. Server Operation Changes

- Allow IPv6 server connections (Nigel Kukard, Johan Jordaan, Bruce, Tom, Kurt Roeckx, Andrew Dunstan)
- Fix SSL to handle errors cleanly (Nathan Mueller)

  In prior releases, certain SSL API error reports were not handled correctly. This release fixes those problems.
- SSL protocol security and performance improvements (Sean Chittenden)

  SSL key renegotiation was happening too frequently, causing poor SSL performance. Also, initial key handling was improved.
- Print lock information when a deadlock is detected (Tom)

  This allows easier debugging of deadlock situations.
- Update `/tmp` socket modification times regularly to avoid their removal (Tom)

  This should help prevent `/tmp` directory cleaner administration scripts from removing server socket files.
- Enable PAM for Mac OS X (Aaron Hillegass)

- Make B-tree indexes fully WAL-safe (Tom)

  In prior releases, under certain rare cases, a server crash could cause B-tree indexes to become corrupt. This release removes those last few rare cases.

- Allow B-tree index compaction and empty page reuse (Tom)
- Fix inconsistent index lookups during split of first root page (Tom)

  In prior releases, when a single-page index split into two pages, there was a brief period when another database session could miss seeing an index entry. This release fixes that rare failure case.

- Improve free space map allocation logic (Tom)
- Preserve free space information between server restarts (Tom)

  In prior releases, the free space map was not saved when the postmaster was stopped, so newly started servers had no free space information. This release saves the free space map, and reloads it when the server is restarted.

- Add start time to `pg_stat_activity` (Neil)
- New code to detect corrupt disk pages; erase with `zero_damaged_pages` (Tom)
- New client/server protocol: faster, no username length limit, allow clean exit from `COPY` (Tom)
- Add transaction status, table ID, column ID to client/server protocol (Tom)
- Add binary I/O to client/server protocol (Tom)
- Remove autocommit server setting; move to client applications (Tom)
- New error message wording, error codes, and three levels of error detail (Tom, Joe, Peter)

E.209.3.2. Performance Improvements

- Add hashing for `GROUP BY` aggregates (Tom)
- Make nested-loop joins be smarter about multicolumn indexes (Tom)
- Allow multikey hash joins (Tom)
- Improve constant folding (Tom)
- Add ability to inline simple SQL functions (Tom)
- Reduce memory usage for queries using complex functions (Tom)

  In prior releases, functions returning allocated memory would not free it until the query completed. This release allows the freeing of function-allocated memory when the function call completes, reducing the total memory used by functions.

- Improve GEQO optimizer performance (Tom)

  This release fixes several inefficiencies in the way the GEQO optimizer manages potential query paths.

- Allow `IN`/`NOT IN` to be handled via hash tables (Tom)
- Improve `NOT IN (`*`subquery`*`)` performance (Tom)
- Allow most `IN` subqueries to be processed as joins (Tom)
- Pattern matching operations can use indexes regardless of locale (Peter)

  There is no way for non-ASCII locales to use the standard indexes for `LIKE` comparisons. This release adds a way to create a special index for `LIKE`.

- Allow the postmaster to preload libraries using `preload_libraries` (Joe)

  For shared libraries that require a long time to load, this option is available so the library can be preloaded in the postmaster and inherited by all database sessions.
- Improve optimizer cost computations, particularly for subqueries (Tom)
- Avoid sort when subquery `ORDER BY` matches upper query (Tom)
- Deduce that `WHERE a.x = b.y AND b.y = 42` also means `a.x = 42` (Tom)
- Allow hash/merge joins on complex joins (Tom)
- Allow hash joins for more data types (Tom)
- Allow join optimization of explicit inner joins, disable with `join_collapse_limit` (Tom)
- Add parameter `from_collapse_limit` to control conversion of subqueries to joins (Tom)
- Use faster and more powerful regular expression code from Tcl (Henry Spencer, Tom)
- Use bit-mapped relation sets in the optimizer (Tom)
- Improve connection startup time (Tom)

  The new client/server protocol requires fewer network packets to start a database session.
- Improve trigger/constraint performance (Stephan)
- Improve speed of `col IN (const, const, const, ...)` (Tom)
- Fix hash indexes which were broken in rare cases (Tom)
- Improve hash index concurrency and speed (Tom)

  Prior releases suffered from poor hash index performance, particularly for high concurrency situations. This release fixes that, and the development group is interested in reports comparing B-tree and hash index performance.
- Align shared buffers on 32-byte boundary for copy speed improvement (Manfred Spraul)

  Certain CPU's perform faster data copies when addresses are 32-byte aligned.
- Data type `numeric` reimplemented for better performance (Tom)

  `numeric` used to be stored in base 100. The new code uses base 10000, for significantly better performance.

E.209.3.3. Server Configuration Changes

- Rename server parameter `server_min_messages` to `log_min_messages` (Bruce)

  This was done so most parameters that control the server logs begin with `log_`.
- Rename `show_*_stats` to `log_*_stats` (Bruce)
- Rename `show_source_port` to `log_source_port` (Bruce)
- Rename `hostname_lookup` to `log_hostname` (Bruce)
- Add `checkpoint_warning` to warn of excessive checkpointing (Bruce)

  In prior releases, it was difficult to determine if checkpoint was happening too frequently. This feature adds a warning to the server logs when excessive checkpointing happens.
- New read-only server parameters for localization (Tom)
- Change debug server log messages to output as `DEBUG` rather than `LOG` (Bruce)

- Prevent server log variables from being turned off by non-superusers (Bruce)

  This is a security feature so non-superusers cannot disable logging that was enabled by the administrator.

- `log_min_messages`/`client_min_messages` now controls `debug_*` output (Bruce)

  This centralizes client debug information so all debug output can be sent to either the client or server logs.

- Add Mac OS X Rendezvous server support (Chris Campbell)

  This allows Mac OS X hosts to query the network for available PostgreSQL servers.

- Add ability to print only slow statements using `log_min_duration_statement` (Christopher)

  This is an often requested debugging feature that allows administrators to see only slow queries in their server logs.

- Allow `pg_hba.conf` to accept netmasks in CIDR format (Andrew Dunstan)

  This allows administrators to merge the host IP address and netmask fields into a single CIDR field in `pg_hba.conf`.

- New read-only parameter `is_superuser` (Tom)

- New parameter `log_error_verbosity` to control error detail (Tom)

  This works with the new error reporting feature to supply additional error information like hints, file names and line numbers.

- `postgres --describe-config` now dumps server config variables (Aizaz Ahmed, Peter)

  This option is useful for administration tools that need to know the configuration variable names and their minimums, maximums, defaults, and descriptions.

- Add new columns in `pg_settings`: `context`, `type`, `source`, `min_val`, `max_val` (Joe)

- Make default `shared_buffers` 1000 and `max_connections` 100, if possible (Tom)

  Prior versions defaulted to 64 shared buffers so PostgreSQL would start on even very old systems. This release tests the amount of shared memory allowed by the platform and selects more reasonable default values if possible. Of course, users are still encouraged to evaluate their resource load and size `shared_buffers` accordingly.

- New `pg_hba.conf` record type `hostnossl` to prevent SSL connections (Jon Jensen)

  In prior releases, there was no way to prevent SSL connections if both the client and server supported SSL. This option allows that capability.

- Remove parameter `geqo_random_seed` (Tom)

- Add server parameter `regex_flavor` to control regular expression processing (Tom)

- Make `pg_ctl` better handle nonstandard ports (Greg)

E.209.3.4. Query Changes

- New SQL-standard information schema (Peter)

- Add read-only transactions (Peter)

- Print key name and value in foreign-key violation messages (Dmitry Tkach)

- Allow users to see their own queries in `pg_stat_activity` (Kevin Brown)

In prior releases, only the superuser could see query strings using `pg_stat_activity`. Now ordinary users can see their own query strings.

- Fix aggregates in subqueries to match SQL standard (Tom)

  The SQL standard says that an aggregate function appearing within a nested subquery belongs to the outer query if its argument contains only outer-query variables. Prior PostgreSQL releases did not handle this fine point correctly.

- Add option to prevent auto-addition of tables referenced in query (Nigel J. Andrews)

  By default, tables mentioned in the query are automatically added to the `FROM` clause if they are not already there. This is compatible with historic POSTGRES behavior but is contrary to the SQL standard. This option allows selecting standard-compatible behavior.

- Allow `UPDATE ... SET col = DEFAULT` (Rod)

  This allows `UPDATE` to set a column to its declared default value.

- Allow expressions to be used in `LIMIT`/`OFFSET` (Tom)

  In prior releases, `LIMIT`/`OFFSET` could only use constants, not expressions.

- Implement `CREATE TABLE AS EXECUTE` (Neil, Peter)

E.209.3.5. Object Manipulation Changes

- Make `CREATE SEQUENCE` grammar more conforming to SQL:2003 (Neil)
- Add statement-level triggers (Neil)

  While this allows a trigger to fire at the end of a statement, it does not allow the trigger to access all rows modified by the statement. This capability is planned for a future release.

- Add check constraints for domains (Rod)

  This greatly increases the usefulness of domains by allowing them to use check constraints.

- Add `ALTER DOMAIN` (Rod)

  This allows manipulation of existing domains.

- Fix several zero-column table bugs (Tom)

  PostgreSQL supports zero-column tables. This fixes various bugs that occur when using such tables.

- Have `ALTER TABLE ... ADD PRIMARY KEY` add not-null constraint (Rod)

  In prior releases, `ALTER TABLE ... ADD PRIMARY` would add a unique index, but not a not-null constraint. That is fixed in this release.

- Add `ALTER TABLE ... WITHOUT OIDS` (Rod)

  This allows control over whether new and updated rows will have an OID column. This is most useful for saving storage space.

- Add `ALTER SEQUENCE` to modify minimum, maximum, increment, cache, cycle values (Rod)
- Add `ALTER TABLE ... CLUSTER ON` (Alvaro Herrera)

  This command is used by `pg_dump` to record the cluster column for each table previously clustered. This information is used by database-wide cluster to cluster all previously clustered tables.

- Improve automatic type casting for domains (Rod, Tom)
- Allow dollar signs in identifiers, except as first character (Tom)

- Disallow dollar signs in operator names, so `x=$1` works (Tom)
- Allow copying table schema using `LIKE` *`subtable`*, also SQL:2003 feature `INCLUDING DEFAULTS` (Rod)
- Add `WITH GRANT OPTION` clause to `GRANT` (Peter)

  This enabled `GRANT` to give other users the ability to grant privileges on an object.

E.209.3.6. Utility Command Changes

- Add `ON COMMIT` clause to `CREATE TABLE` for temporary tables (Gavin)

  This adds the ability for a table to be dropped or all rows deleted on transaction commit.
- Allow cursors outside transactions using `WITH HOLD` (Neil)

  In previous releases, cursors were removed at the end of the transaction that created them. Cursors can now be created with the `WITH HOLD` option, which allows them to continue to be accessed after the creating transaction has committed.
- `FETCH 0` and `MOVE 0` now do nothing (Bruce)

  In previous releases, `FETCH 0` fetched all remaining rows, and `MOVE 0` moved to the end of the cursor.
- Cause `FETCH` and `MOVE` to return the number of rows fetched/moved, or zero if at the beginning/end of cursor, per SQL standard (Bruce)

  In prior releases, the row count returned by `FETCH` and `MOVE` did not accurately reflect the number of rows processed.
- Properly handle `SCROLL` with cursors, or report an error (Neil)

  Allowing random access (both forward and backward scrolling) to some kinds of queries cannot be done without some additional work. If `SCROLL` is specified when the cursor is created, this additional work will be performed. Furthermore, if the cursor has been created with `NO SCROLL`, no random access is allowed.
- Implement SQL-compatible options `FIRST`, `LAST`, `ABSOLUTE` *`n`*, `RELATIVE` *`n`* for `FETCH` and `MOVE` (Tom)
- Allow `EXPLAIN` on `DECLARE CURSOR` (Tom)
- Allow `CLUSTER` to use index marked as pre-clustered by default (Alvaro Herrera)
- Allow `CLUSTER` to cluster all tables (Alvaro Herrera)

  This allows all previously clustered tables in a database to be reclustered with a single command.
- Prevent `CLUSTER` on partial indexes (Tom)
- Allow DOS and Mac line-endings in `COPY` files (Bruce)
- Disallow literal carriage return as a data value, backslash-carriage-return and `\r` are still allowed (Bruce)
- `COPY` changes (binary, `\.`) (Tom)
- Recover from `COPY` failure cleanly (Tom)
- Prevent possible memory leaks in `COPY` (Tom)
- Make `TRUNCATE` transaction-safe (Rod)

`TRUNCATE` can now be used inside a transaction. If the transaction aborts, the changes made by the `TRUNCATE` are automatically rolled back.

- Allow prepare/bind of utility commands like `FETCH` and `EXPLAIN` (Tom)
- Add `EXPLAIN EXECUTE` (Neil)
- Improve `VACUUM` performance on indexes by reducing WAL traffic (Tom)
- Functional indexes have been generalized into indexes on expressions (Tom)

  In prior releases, functional indexes only supported a simple function applied to one or more column names. This release allows any type of scalar expression.
- Have `SHOW TRANSACTION ISOLATION` match input to `SET TRANSACTION ISOLATION` (Tom)
- Have `COMMENT ON DATABASE` on nonlocal database generate a warning, rather than an error (Rod)

  Database comments are stored in database-local tables so comments on a database have to be stored in each database.
- Improve reliability of `LISTEN`/`NOTIFY` (Tom)
- Allow `REINDEX` to reliably reindex nonshared system catalog indexes (Tom)

  This allows system tables to be reindexed without the requirement of a standalone session, which was necessary in previous releases. The only tables that now require a standalone session for reindexing are the global system tables `pg_database`, `pg_shadow`, and `pg_group`.

E.209.3.7. Data Type and Function Changes

- New server parameter `extra_float_digits` to control precision display of floating-point numbers (Pedro Ferreira, Tom)

  This controls output precision which was causing regression testing problems.
- Allow `+1300` as a numeric time-zone specifier, for FJST (Tom)
- Remove rarely used functions `oidrand`, `oidsrand`, and `userfntest` functions (Neil)
- Add `md5()` function to main server, already in `contrib/pgcrypto` (Joe)

  An MD5 function was frequently requested. For more complex encryption capabilities, use `contrib/pgcrypto`.
- Increase date range of `timestamp` (John Cochran)
- Change `EXTRACT(EPOCH FROM timestamp)` so `timestamp without time zone` is assumed to be in local time, not GMT (Tom)
- Trap division by zero in case the operating system doesn't prevent it (Tom)
- Change the `numeric` data type internally to base 10000 (Tom)
- New `hostmask()` function (Greg Wickham)
- Fixes for `to_char()` and `to_timestamp()` (Karel)
- Allow functions that can take any argument data type and return any data type, using `anyelement` and `anyarray` (Joe)

  This allows the creation of functions that can work with any data type.
- Arrays can now be specified as `ARRAY[1,2,3]`, `ARRAY[['a','b'],['c','d']]`, or `ARRAY[ARRAY[ARRAY[2]]]` (Joe)

- Allow proper comparisons for arrays, including `ORDER BY` and `DISTINCT` support (Joe)
- Allow indexes on array columns (Joe)
- Allow array concatenation with `||` (Joe)
- Allow `WHERE` qualification *`expr op`* `ANY/SOME/ALL (`*`array_expr`*`)` (Joe)

  This allows arrays to behave like a list of values, for purposes like `SELECT * FROM tab WHERE col IN (array_val)`.
- New array functions `array_append`, `array_cat`, `array_lower`, `array_prepend`, `array_to_string`, `array_upper`, `string_to_array` (Joe)
- Allow user defined aggregates to use polymorphic functions (Joe)
- Allow assignments to empty arrays (Joe)
- Allow 60 in seconds fields of `time`, `timestamp`, and `interval` input values (Tom)

  Sixty-second values are needed for leap seconds.
- Allow `cidr` data type to be cast to `text` (Tom)
- Disallow invalid time zone names in SET TIMEZONE
- Trim trailing spaces when `char` is cast to `varchar` or `text` (Tom)
- Make `float(`*`p`*`)` measure the precision *`p`* in binary digits, not decimal digits (Tom)
- Add IPv6 support to the `inet` and `cidr` data types (Michael Graff)
- Add `family()` function to report whether address is IPv4 or IPv6 (Michael Graff)
- Have `SHOW datestyle` generate output similar to that used by `SET datestyle` (Tom)
- Make `EXTRACT(TIMEZONE)` and `SET/SHOW TIME ZONE` follow the SQL convention for the sign of time zone offsets, i.e., positive is east from UTC (Tom)
- Fix `date_trunc('quarter', ...)` (Böjthe Zoltán)

  Prior releases returned an incorrect value for this function call.
- Make `initcap()` more compatible with Oracle (Mike Nolan)

  `initcap()` now uppercases a letter appearing after any non-alphanumeric character, rather than only after whitespace.
- Allow only `datestyle` field order for date values not in ISO-8601 format (Greg)
- Add new `datestyle` values `MDY`, `DMY`, and `YMD` to set input field order; honor `US` and `European` for backward compatibility (Tom)
- String literals like `'now'` or `'today'` will no longer work as a column default. Use functions such as `now()`, `current_timestamp` instead. (change required for prepared statements) (Tom)
- Treat NaN as larger than any other value in `min()`/`max()` (Tom)

  NaN was already sorted after ordinary numeric values for most purposes, but `min()` and `max()` didn't get this right.
- Prevent interval from suppressing `:00` seconds display
- New functions `pg_get_triggerdef(prettyprint)` and `pg_conversion_is_visible()` (Christopher)
- Allow time to be specified as `040506` or `0405` (Tom)
- Input date order must now be `YYYY-MM-DD` (with 4-digit year) or match `datestyle`
- Make `pg_get_constraintdef` support unique, primary-key, and check constraints (Christopher)

E.209.3.8. Server-Side Language Changes

- Prevent PL/pgSQL crash when `RETURN NEXT` is used on a zero-row record variable (Tom)
- Make PL/Python's `spi_execute` interface handle null values properly (Andrew Bosma)
- Allow PL/pgSQL to declare variables of composite types without `%ROWTYPE` (Tom)
- Fix PL/Python's `_quote()` function to handle big integers
- Make PL/Python an untrusted language, now called `plpythonu` (Kevin Jacobs, Tom)

  The Python language no longer supports a restricted execution environment, so the trusted version of PL/Python was removed. If this situation changes, a version of PL/Python that can be used by non-superusers will be readded.
- Allow polymorphic PL/pgSQL functions (Joe, Tom)
- Allow polymorphic SQL functions (Joe)
- Improved compiled function caching mechanism in PL/pgSQL with full support for polymorphism (Joe)
- Add new parameter `$0` in PL/pgSQL representing the function's actual return type (Joe)
- Allow PL/Tcl and PL/Python to use the same trigger on multiple tables (Tom)
- Fixed PL/Tcl's `spi_prepare` to accept fully qualified type names in the parameter type list (Jan)

E.209.3.9. psql Changes

- Add `\pset pager always` to always use pager (Greg)

  This forces the pager to be used even if the number of rows is less than the screen height. This is valuable for rows that wrap across several screen rows.
- Improve tab completion (Rod, Ross Reedstrom, Ian Barwick)
- Reorder `\?` help into groupings (Harald Armin Massa, Bruce)
- Add backslash commands for listing schemas, casts, and conversions (Christopher)
- `\encoding` now changes based on the server parameter `client_encoding` (Tom)

  In previous versions, `\encoding` was not aware of encoding changes made using `SET client_encoding`.
- Save editor buffer into readline history (Ross)

  When `\e` is used to edit a query, the result is saved in the readline history for retrieval using the up arrow.
- Improve `\d` display (Christopher)
- Enhance HTML mode to be more standards-conforming (Greg)
- New `\set AUTOCOMMIT off` capability (Tom)

  This takes the place of the removed server parameter `autocommit`.
- New `\set VERBOSITY` to control error detail (Tom)

  This controls the new error reporting details.
- New prompt escape sequence `%x` to show transaction status (Tom)

- Long options for psql are now available on all platforms

E.209.3.10. pg_dump Changes

- Multiple pg_dump fixes, including tar format and large objects
- Allow pg_dump to dump specific schemas (Neil)
- Make pg_dump preserve column storage characteristics (Christopher)

  This preserves `ALTER TABLE ... SET STORAGE` information.
- Make pg_dump preserve `CLUSTER` characteristics (Christopher)
- Have pg_dumpall use `GRANT`/`REVOKE` to dump database-level privileges (Tom)
- Allow pg_dumpall to support the options `-a`, `-s`, `-x` of pg_dump (Tom)
- Prevent pg_dump from lowercasing identifiers specified on the command line (Tom)
- pg_dump options `--use-set-session-authorization` and `--no-reconnect` now do nothing, all dumps use `SET SESSION AUTHORIZATION`

  pg_dump no longer reconnects to switch users, but instead always uses `SET SESSION AUTHORIZATION`. This will reduce password prompting during restores.
- Long options for pg_dump are now available on all platforms

  PostgreSQL now includes its own long-option processing routines.

E.209.3.11. libpq Changes

- Add function `PQfreemem` for freeing memory on Windows, suggested for `NOTIFY` (Bruce)

  Windows requires that memory allocated in a library be freed by a function in the same library, hence `free()` doesn't work for freeing memory allocated by libpq. `PQfreemem` is the proper way to free libpq memory, especially on Windows, and is recommended for other platforms as well.
- Document service capability, and add sample file (Bruce)

  This allows clients to look up connection information in a central file on the client machine.
- Make `PQsetdbLogin` have the same defaults as `PQconnectdb` (Tom)
- Allow libpq to cleanly fail when result sets are too large (Tom)
- Improve performance of function `PQunescapeBytea` (Ben Lamb)
- Allow thread-safe libpq with `configure` option `--enable-thread-safety` (Lee Kindness, Philip Yarra)
- Allow function `pqInternalNotice` to accept a format string and arguments instead of just a preformatted message (Tom, Sean Chittenden)
- Control SSL negotiation with `sslmode` values `disable`, `allow`, `prefer`, and `require` (Jon Jensen)
- Allow new error codes and levels of text (Tom)
- Allow access to the underlying table and column of a query result (Tom)

  This is helpful for query-builder applications that want to know the underlying table and column names associated with a specific result set.

- Allow access to the current transaction status (Tom)
- Add ability to pass binary data directly to the server (Tom)
- Add function `PQexecPrepared` and `PQsendQueryPrepared` functions which perform bind/execute of previously prepared statements (Tom)

E.209.3.12. JDBC Changes

- Allow `setNull` on updateable result sets
- Allow `executeBatch` on a prepared statement (Barry)
- Support SSL connections (Barry)
- Handle schema names in result sets (Paul Sorenson)
- Add refcursor support (Nic Ferrier)

E.209.3.13. Miscellaneous Interface Changes

- Prevent possible memory leak or core dump during libpgtcl shutdown (Tom)
- Add Informix compatibility to ECPG (Michael)

  This allows ECPG to process embedded C programs that were written using certain Informix extensions.
- Add type `decimal` to ECPG that is fixed length, for Informix (Michael)
- Allow thread-safe embedded SQL programs with `configure` option `--enable-thread-safety` (Lee Kindness, Bruce)

  This allows multiple threads to access the database at the same time.
- Moved Python client PyGreSQL to http://www.pygresql.org (Marc)

E.209.3.14. Source Code Changes

- Prevent need for separate platform geometry regression result files (Tom)
- Improved PPC locking primitive (Reinhard Max)
- New function `palloc0` to allocate and clear memory (Bruce)
- Fix locking code for s390x CPU (64-bit) (Tom)
- Allow OpenBSD to use local ident credentials (William Ahern)
- Make query plan trees read-only to executor (Tom)
- Add Darwin startup scripts (David Wheeler)
- Allow libpq to compile with Borland C++ compiler (Lester Godwin, Karl Waclawek)
- Use our own version of `getopt_long()` if needed (Peter)
- Convert administration scripts to C (Peter)
- Bison >= 1.85 is now required to build the PostgreSQL grammar, if building from CVS

- Merge documentation into one book (Peter)
- Add Windows compatibility functions (Bruce)
- Allow client interfaces to compile under MinGW (Bruce)
- New `ereport()` function for error reporting (Tom)
- Support Intel compiler on Linux (Peter)
- Improve Linux startup scripts (Slawomir Sudnik, Darko Prenosil)
- Add support for AMD Opteron and Itanium (Jeffrey W. Baker, Bruce)
- Remove `--enable-recode` option from `configure`

  This was no longer needed now that we have `CREATE CONVERSION`.
- Generate a compile error if spinlock code is not found (Bruce)

  Platforms without spinlock code will now fail to compile, rather than silently using semaphores. This failure can be disabled with a new `configure` option.

E.209.3.15. Contrib Changes

- Change dbmirror license to BSD
- Improve earthdistance (Bruno Wolff III)
- Portability improvements to pgcrypto (Marko Kreen)
- Prevent crash in xml (John Gray, Michael Richards)
- Update oracle
- Update mysql
- Update cube (Bruno Wolff III)
- Update earthdistance to use cube (Bruno Wolff III)
- Update btree_gist (Oleg)
- New tsearch2 full-text search module (Oleg, Teodor)
- Add hash-based crosstab function to tablefuncs (Joe)
- Add serial column to order `connectby()` siblings in tablefuncs (Nabil Sayegh,Joe)
- Add named persistent connections to dblink (Shridhar Daithanka)
- New pg_autovacuum allows automatic `VACUUM` (Matthew T. O'Connor)
- Make pgbench honor environment variables `PGHOST`, `PGPORT`, `PGUSER` (Tatsuo)
- Improve intarray (Teodor Sigaev)
- Improve pgstattuple (Rod)
- Fix bug in `metaphone()` in fuzzystrmatch
- Improve adddepend (Rod)
- Update spi/timetravel (Böjthe Zoltán)
- Fix dbase `-s` option and improve non-ASCII handling (Thomas Behr, Márcio Smiderle)
- Remove array module because features now included by default (Joe)

E.210. Release 7.3.21

Release Date: 2008-01-07

This release contains a variety of fixes from 7.3.20, including fixes for significant security issues.

This is expected to be the last PostgreSQL release in the 7.3.X series. Users are encouraged to update to a newer release branch soon.

E.210.1. Migration to Version 7.3.21

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.210.2. Changes

- Prevent functions in indexes from executing with the privileges of the user running `VACUUM`, `ANALYZE`, etc (Tom)

  Functions used in index expressions and partial-index predicates are evaluated whenever a new table entry is made. It has long been understood that this poses a risk of trojan-horse code execution if one modifies a table owned by an untrustworthy user. (Note that triggers, defaults, check constraints, etc. pose the same type of risk.) But functions in indexes pose extra danger because they will be executed by routine maintenance operations such as `VACUUM FULL`, which are commonly performed automatically under a superuser account. For example, a nefarious user can execute code with superuser privileges by setting up a trojan-horse index definition and waiting for the next routine vacuum. The fix arranges for standard maintenance operations (including `VACUUM`, `ANALYZE`, `REINDEX`, and `CLUSTER`) to execute as the table owner rather than the calling user, using the same privilege-switching mechanism already used for `SECURITY DEFINER` functions. To prevent bypassing this security measure, execution of `SET SESSION AUTHORIZATION` and `SET ROLE` is now forbidden within a `SECURITY DEFINER` context. (CVE-2007-6600)

- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

  The fix that appeared for this in 7.3.20 was incomplete, as it plugged the hole for only some `dblink` functions. (CVE-2007-6601, CVE-2007-3278)

- Fix potential crash in `translate()` when using a multibyte database encoding (Tom)

- Make `contrib/tablefunc`'s `crosstab()` handle NULL rowid as a category in its own right, rather than crashing (Joe)

- Require a specific version of Autoconf to be used when re-generating the `configure` script (Peter)

  This affects developers and packagers only. The change was made to prevent accidental use of untested combinations of Autoconf and PostgreSQL versions. You can remove the version check if you really want to use a different Autoconf version, but it's your responsibility whether the result works or not.

E.211. Release 7.3.20

Release Date: 2007-09-17

This release contains fixes from 7.3.19.

E.211.1. Migration to Version 7.3.20

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.211.2. Changes

- Prevent index corruption when a transaction inserts rows and then aborts close to the end of a concurrent `VACUUM` on the same table (Tom)
- Make `CREATE DOMAIN ... DEFAULT NULL` work properly (Tom)
- Fix crash when `log_min_error_statement` logging runs out of memory (Tom)
- Require non-superusers who use `/contrib/dblink` to use only password authentication, as a security measure (Joe)

E.212. Release 7.3.19

Release Date: 2007-04-23

This release contains fixes from 7.3.18, including a security fix.

E.212.1. Migration to Version 7.3.19

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.212.2. Changes

- Support explicit placement of the temporary-table schema within `search_path`, and disable searching it for functions and operators (Tom)

  This is needed to allow a security-definer function to set a truly secure value of `search_path`. Without it, an unprivileged SQL user can use temporary objects to execute code with the privileges of the security-definer function (CVE-2007-2138). See `CREATE FUNCTION` for more information.

- Fix potential-data-corruption bug in how `VACUUM FULL` handles `UPDATE` chains (Tom, Pavan Deolasee)

E.213. Release 7.3.18

Release Date: 2007-02-05

This release contains a variety of fixes from 7.3.17, including a security fix.

E.213.1. Migration to Version 7.3.18

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.213.2. Changes

- Remove security vulnerability that allowed connected users to read backend memory (Tom)

  The vulnerability involves changing the data type of a table column used in a SQL function (CVE-2007-0555). This error can easily be exploited to cause a backend crash, and in principle might be used to read database content that the user should not be able to access.
- Fix rare bug wherein btree index page splits could fail due to choosing an infeasible split point (Heikki Linnakangas)
- Tighten security of multi-byte character processing for UTF8 sequences over three bytes long (Tom)

E.214. Release 7.3.17

Release Date: 2007-01-08

This release contains a variety of fixes from 7.3.16.

E.214.1. Migration to Version 7.3.17

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.214.2. Changes

- `to_number()` and `to_char(numeric)` are now `STABLE`, not `IMMUTABLE`, for new initdb installs (Tom)

  This is because `lc_numeric` can potentially change the output of these functions.
- Improve index usage of regular expressions that use parentheses (Tom)

  This improves psql `\d` performance also.

E.215. Release 7.3.16

Release Date: 2006-10-16

This release contains a variety of fixes from 7.3.15.

E.215.1. Migration to Version 7.3.16

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.215.2. Changes

- Fix corner cases in pattern matching for psql's `\d` commands
- Fix index-corrupting bugs in /contrib/ltree (Teodor)
- Back-port 7.4 spinlock code to improve performance and support 64-bit architectures better
- Fix SSL-related memory leak in libpq
- Fix backslash escaping in /contrib/dbmirror
- Adjust regression tests for recent changes in US DST laws

E.216. Release 7.3.15

Release Date: 2006-05-23

This release contains a variety of fixes from 7.3.14, including patches for extremely serious security issues.

E.216.1. Migration to Version 7.3.15

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

Full security against the SQL-injection attacks described in CVE-2006-2313 and CVE-2006-2314 might require changes in application code. If you have applications that embed untrustworthy strings into SQL commands, you should examine them as soon as possible to ensure that they are using recommended escaping techniques. In most cases, applications should be using subroutines provided by libraries or drivers (such as libpq's `PQescapeStringConn()`) to perform string escaping, rather than relying on *ad hoc* code to do it.

E.216.2. Changes

- Change the server to reject invalidly-encoded multibyte characters in all cases (Tatsuo, Tom)

  While PostgreSQL has been moving in this direction for some time, the checks are now applied uniformly to all encodings and all textual input, and are now always errors not merely warnings. This change defends against SQL-injection attacks of the type described in CVE-2006-2313.

- Reject unsafe uses of `\'` in string literals

  As a server-side defense against SQL-injection attacks of the type described in CVE-2006-2314, the server now only accepts `''` and not `\'` as a representation of ASCII single quote in SQL string literals. By default, `\'` is rejected only when `client_encoding` is set to a client-only encoding (SJIS, BIG5, GBK, GB18030, or UHC), which is the scenario in which SQL injection is possible. A new configuration parameter `backslash_quote` is available to adjust this behavior when needed. Note that full security against CVE-2006-2314 might require client-side changes; the purpose of `backslash_quote` is in part to make it obvious that insecure clients are insecure.

- Modify libpq's string-escaping routines to be aware of encoding considerations

  This fixes libpq-using applications for the security issues described in CVE-2006-2313 and CVE-2006-2314. Applications that use multiple PostgreSQL connections concurrently should migrate to `PQescapeStringConn()` and `PQescapeByteaConn()` to ensure that escaping is done correctly for the settings in use in each database connection. Applications that do string escaping "by hand" should be modified to rely on library routines instead.

- Fix some incorrect encoding conversion functions

  `win1251_to_iso`, `alt_to_iso`, `euc_tw_to_big5`, `euc_tw_to_mic`, `mic_to_euc_tw` were all broken to varying extents.

- Clean up stray remaining uses of `\'` in strings (Bruce, Jan)

- Fix server to use custom DH SSL parameters correctly (Michael Fuhr)

- Fix various minor memory leaks

E.217. Release 7.3.14

Release Date: 2006-02-14

This release contains a variety of fixes from 7.3.13.

E.217.1. Migration to Version 7.3.14

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.13, see Section E.218.

E.217.2. Changes

- Fix potential crash in `SET SESSION AUTHORIZATION` (CVE-2006-0553)

  An unprivileged user could crash the server process, resulting in momentary denial of service to other users, if the server has been compiled with Asserts enabled (which is not the default). Thanks to Akio Ishida for reporting this problem.

- Fix bug with row visibility logic in self-inserted rows (Tom)

  Under rare circumstances a row inserted by the current command could be seen as already valid, when it should not be. Repairs bug created in 7.3.11 release.

- Fix race condition that could lead to "file already exists" errors during pg_clog file creation (Tom)
- Fix to allow restoring dumps that have cross-schema references to custom operators (Tom)
- Portability fix for testing presence of `finite` and `isinf` during configure (Tom)

E.218. Release 7.3.13

Release Date: 2006-01-09

This release contains a variety of fixes from 7.3.12.

E.218.1. Migration to Version 7.3.13

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.10, see Section E.221. Also, you might need to `REINDEX` indexes on textual columns after updating, if you are affected by the locale or plperl issues described below.

E.218.2. Changes

- Fix character string comparison for locales that consider different character combinations as equal, such as Hungarian (Tom)

  This might require `REINDEX` to fix existing indexes on textual columns.

- Set locale environment variables during postmaster startup to ensure that plperl won't change the locale later

This fixes a problem that occurred if the postmaster was started with environment variables specifying a different locale than what initdb had been told. Under these conditions, any use of plperl was likely to lead to corrupt indexes. You might need `REINDEX` to fix existing indexes on textual columns if this has happened to you.

- Fix longstanding bug in strpos() and regular expression handling in certain rarely used Asian multibyte character sets (Tatsuo)
- Fix bug in `/contrib/pgcrypto` gen_salt, which caused it not to use all available salt space for MD5 and XDES algorithms (Marko Kreen, Solar Designer)

  Salts for Blowfish and standard DES are unaffected.
- Fix `/contrib/dblink` to throw an error, rather than crashing, when the number of columns specified is different from what's actually returned by the query (Joe)

E.219. Release 7.3.12

Release Date: 2005-12-12

This release contains a variety of fixes from 7.3.11.

E.219.1. Migration to Version 7.3.12

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.10, see Section E.221.

E.219.2. Changes

- Fix race condition in transaction log management

  There was a narrow window in which an I/O operation could be initiated for the wrong page, leading to an Assert failure or data corruption.
- `/contrib/ltree` fixes (Teodor)
- Fix longstanding planning error for outer joins

  This bug sometimes caused a bogus error "RIGHT JOIN is only supported with merge-joinable join conditions".
- Prevent core dump in pg_autovacuum when a table has been dropped

E.220. Release 7.3.11

Release Date: 2005-10-04

This release contains a variety of fixes from 7.3.10.

E.220.1. Migration to Version 7.3.11

A dump/restore is not required for those running 7.3.X. However, if you are upgrading from a version earlier than 7.3.10, see Section E.221.

E.220.2. Changes

- Fix error that allowed `VACUUM` to remove `ctid` chains too soon, and add more checking in code that follows `ctid` links

  This fixes a long-standing problem that could cause crashes in very rare circumstances.

- Fix `CHAR()` to properly pad spaces to the specified length when using a multiple-byte character set (Yoshiyuki Asaba)

  In prior releases, the padding of `CHAR()` was incorrect because it only padded to the specified number of bytes without considering how many characters were stored.

- Fix missing rows in queries like `UPDATE a=... WHERE a...` with GiST index on column `a`
- Improve checking for partially-written WAL pages
- Improve robustness of signal handling when SSL is enabled
- Various memory leakage fixes
- Various portability improvements
- Fix PL/pgSQL to handle `var := var` correctly when the variable is of pass-by-reference type

E.221. Release 7.3.10

Release Date: 2005-05-09

This release contains a variety of fixes from 7.3.9, including several security-related issues.

E.221.1. Migration to Version 7.3.10

A dump/restore is not required for those running 7.3.X. However, it is one possible way of handling a significant security problem that has been found in the initial contents of 7.3.X system catalogs. A dump/initdb/reload sequence using 7.3.10's initdb will automatically correct this problem.

The security problem is that the built-in character set encoding conversion functions can be invoked from SQL commands by unprivileged users, but the functions were not designed for such use and are not secure against malicious choices of arguments. The fix involves changing the declared parameter list of these functions so that they can no longer be invoked from SQL commands. (This does not affect their normal use by the encoding conversion machinery.) It is strongly recommended that all installations repair this error, either by initdb or by following the manual repair procedure given below.

The error at least allows unprivileged database users to crash their server process, and might allow unprivileged users to gain the privileges of a database superuser.

If you wish not to do an initdb, perform the following procedure instead. As the database superuser, do:

```
BEGIN;
UPDATE pg_proc SET proargtypes[3] = 'internal'::regtype
WHERE pronamespace = 11 AND pronargs = 5
     AND proargtypes[2] = 'cstring'::regtype;
-- The command should report having updated 90 rows;
-- if not, rollback and investigate instead of committing!
COMMIT;
```

The above procedure must be carried out in *each* database of an installation, including `template1`, and ideally including `template0` as well. If you do not fix the template databases then any subsequently created databases will contain the same error. `template1` can be fixed in the same way as any other database, but fixing `template0` requires additional steps. First, from any database issue:

```
UPDATE pg_database SET datallowconn = true WHERE datname = 'template0';
```

Next connect to `template0` and perform the above repair procedure. Finally, do:

```
-- re-freeze template0:
VACUUM FREEZE;
-- and protect it against future alterations:
UPDATE pg_database SET datallowconn = false WHERE datname = 'template0';
```

E.221.2. Changes

- Change encoding function signature to prevent misuse
- Repair ancient race condition that allowed a transaction to be seen as committed for some purposes (eg SELECT FOR UPDATE) slightly sooner than for other purposes

  This is an extremely serious bug since it could lead to apparent data inconsistencies being briefly visible to applications.
- Repair race condition between relation extension and VACUUM

  This could theoretically have caused loss of a page's worth of freshly-inserted data, although the scenario seems of very low probability. There are no known cases of it having caused more than an Assert failure.
- Fix comparisons of `TIME WITH TIME ZONE` values

  The comparison code was wrong in the case where the `--enable-integer-datetimes` configuration switch had been used. NOTE: if you have an index on a `TIME WITH TIME ZONE` column, it will need to be `REINDEX`ed after installing this update, because the fix corrects the sort order of column values.
- Fix `EXTRACT(EPOCH)` for `TIME WITH TIME ZONE` values
- Fix mis-display of negative fractional seconds in `INTERVAL` values

This error only occurred when the `--enable-integer-datetimes` configuration switch had been used.

- Additional buffer overrun checks in plpgsql (Neil)
- Fix pg_dump to dump trigger names containing `%` correctly (Neil)
- Prevent `to_char(interval)` from dumping core for month-related formats
- Fix `contrib/pgcrypto` for newer OpenSSL builds (Marko Kreen)
- Still more 64-bit fixes for `contrib/intagg`
- Prevent incorrect optimization of functions returning `RECORD`

E.222. Release 7.3.9

Release Date: 2005-01-31

This release contains a variety of fixes from 7.3.8, including several security-related issues.

E.222.1. Migration to Version 7.3.9

A dump/restore is not required for those running 7.3.X.

E.222.2. Changes

- Disallow `LOAD` to non-superusers

  On platforms that will automatically execute initialization functions of a shared library (this includes at least Windows and ELF-based Unixen), `LOAD` can be used to make the server execute arbitrary code. Thanks to NGS Software for reporting this.
- Check that creator of an aggregate function has the right to execute the specified transition functions

  This oversight made it possible to bypass denial of EXECUTE permission on a function.
- Fix security and 64-bit issues in contrib/intagg
- Add needed STRICT marking to some contrib functions (Kris Jurka)
- Avoid buffer overrun when plpgsql cursor declaration has too many parameters (Neil)
- Fix planning error for FULL and RIGHT outer joins

  The result of the join was mistakenly supposed to be sorted the same as the left input. This could not only deliver mis-sorted output to the user, but in case of nested merge joins could give outright wrong answers.
- Fix plperl for quote marks in tuple fields
- Fix display of negative intervals in SQL and GERMAN datestyles

E.223. Release 7.3.8

Release Date: 2004-10-22

This release contains a variety of fixes from 7.3.7.

E.223.1. Migration to Version 7.3.8

A dump/restore is not required for those running 7.3.X.

E.223.2. Changes

- Repair possible failure to update hint bits on disk

  Under rare circumstances this oversight could lead to "could not access transaction status" failures, which qualifies it as a potential-data-loss bug.

- Ensure that hashed outer join does not miss tuples

  Very large left joins using a hash join plan could fail to output unmatched left-side rows given just the right data distribution.

- Disallow running pg_ctl as root

  This is to guard against any possible security issues.

- Avoid using temp files in /tmp in make_oidjoins_check

  This has been reported as a security issue, though it's hardly worthy of concern since there is no reason for non-developers to use this script anyway.

E.224. Release 7.3.7

Release Date: 2004-08-16

This release contains one critical fix over 7.3.6, and some minor items.

E.224.1. Migration to Version 7.3.7

A dump/restore is not required for those running 7.3.X.

E.224.2. Changes

- Prevent possible loss of committed transactions during crash

Due to insufficient interlocking between transaction commit and checkpointing, it was possible for transactions committed just before the most recent checkpoint to be lost, in whole or in part, following a database crash and restart. This is a serious bug that has existed since PostgreSQL 7.1.

- Remove asymmetrical word processing in tsearch (Teodor)
- Properly schema-qualify function names when pg_dump'ing a CAST

E.225. Release 7.3.6

Release Date: 2004-03-02

This release contains a variety of fixes from 7.3.5.

E.225.1. Migration to Version 7.3.6

A dump/restore is *not* required for those running 7.3.*.

E.225.2. Changes

- Revert erroneous changes in rule permissions checking

  A patch applied in 7.3.3 to fix a corner case in rule permissions checks turns out to have disabled rule-related permissions checks in many not-so-corner cases. This would for example allow users to insert into views they weren't supposed to have permission to insert into. We have therefore reverted the 7.3.3 patch. The original bug will be fixed in 8.0.
- Repair incorrect order of operations in GetNewTransactionId()

  This bug could result in failure under out-of-disk-space conditions, including inability to restart even after disk space is freed.
- Ensure configure selects -fno-strict-aliasing even when an external value for CFLAGS is supplied

  On some platforms, building with -fstrict-aliasing causes bugs.
- Make pg_restore handle 64-bit off_t correctly

  This bug prevented proper restoration from archive files exceeding 4 GB.
- Make contrib/dblink not assume that local and remote type OIDs match (Joe)
- Quote connectby()'s start_with argument properly (Joe)
- Don't crash when a rowtype argument to a plpgsql function is NULL
- Avoid generating invalid character encoding sequences in corner cases when planning LIKE operations
- Ensure text_position() cannot scan past end of source string in multibyte cases (Korea PostgreSQL Users' Group)
- Fix index optimization and selectivity estimates for LIKE operations on bytea columns (Joe)

E.226. Release 7.3.5

Release Date: 2003-12-03

This has a variety of fixes from 7.3.4.

E.226.1. Migration to Version 7.3.5

A dump/restore is *not* required for those running 7.3.*.

E.226.2. Changes

- Force zero_damaged_pages to be on during recovery from WAL
- Prevent some obscure cases of "variable not in subplan target lists"
- Force stats processes to detach from shared memory, ensuring cleaner shutdown
- Make PQescapeBytea and byteaout consistent with each other (Joe)
- Added missing SPI_finish() calls to dblink's get_tuple_of_interest() (Joe)
- Fix for possible foreign key violation when rule rewrites INSERT (Jan)
- Support qualified type names in PL/Tcl's spi_prepare command (Jan)
- Make pg_dump handle a procedural language handler located in pg_catalog
- Make pg_dump handle cases where a custom opclass is in another schema
- Make pg_dump dump binary-compatible casts correctly (Jan)
- Fix insertion of expressions containing subqueries into rule bodies
- Fix incorrect argument processing in clusterdb script (Anand Ranganathan)
- Fix problems with dropped columns in plpython triggers
- Repair problems with to_char() reading past end of its input string (Karel)
- Fix GB18030 mapping errors (Tatsuo)
- Fix several problems with SSL error handling and asynchronous SSL I/O
- Remove ability to bind a list of values to a single parameter in JDBC (prevents possible SQL-injection attacks)
- Fix some errors in HAVE_INT64_TIMESTAMP code paths
- Fix corner case for btree search in parallel with first root page split

E.227. Release 7.3.4

Release Date: 2003-07-24

This has a variety of fixes from 7.3.3.

E.227.1. Migration to Version 7.3.4

A dump/restore is *not* required for those running 7.3.*.

E.227.2. Changes

- Repair breakage in timestamp-to-date conversion for dates before 2000
- Prevent rare possibility of server startup failure (Tom)
- Fix bugs in interval-to-time conversion (Tom)
- Add constraint names in a few places in pg_dump (Rod)
- Improve performance of functions with many parameters (Tom)
- Fix to_ascii() buffer overruns (Tom)
- Prevent restore of database comments from throwing an error (Tom)
- Work around buggy strxfrm() present in some Solaris releases (Tom)
- Properly escape jdbc setObject() strings to improve security (Barry)

E.228. Release 7.3.3

Release Date: 2003-05-22

This release contains a variety of fixes for version 7.3.2.

E.228.1. Migration to Version 7.3.3

A dump/restore is *not* required for those running version 7.3.*.

E.228.2. Changes

- Repair sometimes-incorrect computation of StartUpID after a crash
- Avoid slowness with lots of deferred triggers in one transaction (Stephan)
- Don't lock referenced row when `UPDATE` doesn't change foreign key's value (Jan)
- Use `-fPIC` not `-fpic` on Sparc (Tom Callaway)
- Repair lack of schema-awareness in contrib/reindexdb
- Fix contrib/intarray error for zero-element result array (Teodor)
- Ensure createuser script will exit on control-C (Oliver)

- Fix errors when the type of a dropped column has itself been dropped
- `CHECKPOINT` does not cause database panic on failure in noncritical steps
- Accept 60 in seconds fields of timestamp, time, interval input values
- Issue notice, not error, if `TIMESTAMP(`, `TIME`, or `INTERVAL` precision too large
- Fix `abstime-to-time` cast function (fix is not applied unless you initdb)
- Fix pg_proc entry for `timestampt_izone` (fix is not applied unless you initdb)
- Make `EXTRACT(EPOCH FROM timestamp without time zone)` treat input as local time
- `'now'::timestamptz` gave wrong answer if timezone changed earlier in transaction
- `HAVE_INT64_TIMESTAMP` code for time with timezone overwrote its input
- Accept `GLOBAL TEMP/TEMPORARY` as a synonym for `TEMPORARY`
- Avoid improper schema-privilege-check failure in foreign-key triggers
- Fix bugs in foreign-key triggers for `SET DEFAULT` action
- Fix incorrect time-qual check in row fetch for `UPDATE` and `DELETE` triggers
- Foreign-key clauses were parsed but ignored in `ALTER TABLE ADD COLUMN`
- Fix createlang script breakage for case where handler function already exists
- Fix misbehavior on zero-column tables in pg_dump, COPY, ANALYZE, other places
- Fix misbehavior of `func_error()` on type names containing '%'
- Fix misbehavior of `replace()` on strings containing '%'
- Regular-expression patterns containing certain multibyte characters failed
- Account correctly for `NULL`s in more cases in join size estimation
- Avoid conflict with system definition of `isblank()` function or macro
- Fix failure to convert large code point values in EUC_TW conversions (Tatsuo)
- Fix error recovery for `SSL_read`/`SSL_write` calls
- Don't do early constant-folding of type coercion expressions
- Validate page header fields immediately after reading in any page
- Repair incorrect check for ungrouped variables in unnamed joins
- Fix buffer overrun in `to_ascii` (Guido Notari)
- contrib/ltree fixes (Teodor)
- Fix core dump in deadlock detection on machines where char is unsigned
- Avoid running out of buffers in many-way indexscan (bug introduced in 7.3)
- Fix planner's selectivity estimation functions to handle domains properly
- Fix dbmirror memory-allocation bug (Steven Singer)
- Prevent infinite loop in `ln(numeric)` due to roundoff error
- `GROUP BY` got confused if there were multiple equal GROUP BY items
- Fix bad plan when inherited `UPDATE`/`DELETE` references another inherited table
- Prevent clustering on incomplete (partial or non-NULL-storing) indexes
- Service shutdown request at proper time if it arrives while still starting up

- Fix left-links in temporary indexes (could make backwards scans miss entries)
- Fix incorrect handling of client_encoding setting in postgresql.conf (Tatsuo)
- Fix failure to respond to `pg_ctl stop -m fast` after Async_NotifyHandler runs
- Fix SPI for case where rule contains multiple statements of the same type
- Fix problem with checking for wrong type of access privilege in rule query
- Fix problem with `EXCEPT` in `CREATE RULE`
- Prevent problem with dropping temp tables having serial columns
- Fix replace_vars_with_subplan_refs failure in complex views
- Fix regexp slowness in single-byte encodings (Tatsuo)
- Allow qualified type names in `CREATE CAST` and `DROP CAST`
- Accept `SETOF type[]`, which formerly had to be written `SETOF _type`
- Fix pg_dump core dump in some cases with procedural languages
- Force ISO datestyle in pg_dump output, for portability (Oliver)
- pg_dump failed to handle error return from `lo_read` (Oleg Drokin)
- pg_dumpall failed with groups having no members (Nick Eskelinen)
- pg_dumpall failed to recognize --globals-only switch
- pg_restore failed to restore blobs if -X disable-triggers is specified
- Repair intrafunction memory leak in plpgsql
- pltcl's `elog` command dumped core if given wrong parameters (Ian Harding)
- plpython used wrong value of `atttypmod` (Brad McLean)
- Fix improper quoting of boolean values in Python interface (D'Arcy)
- Added `addDataType()` method to PGConnection interface for JDBC
- Fixed various problems with updateable ResultSets for JDBC (Shawn Green)
- Fixed various problems with DatabaseMetaData for JDBC (Kris Jurka, Peter Royal)
- Fixed problem with parsing table ACLs in JDBC
- Better error message for character set conversion problems in JDBC

E.229. Release 7.3.2

Release Date: 2003-02-04

This release contains a variety of fixes for version 7.3.1.

E.229.1. Migration to Version 7.3.2

A dump/restore is *not* required for those running version 7.3.*.

E.229.2. Changes

- Restore creation of OID column in CREATE TABLE AS / SELECT INTO
- Fix pg_dump core dump when dumping views having comments
- Dump DEFERRABLE/INITIALLY DEFERRED constraints properly
- Fix UPDATE when child table's column numbering differs from parent
- Increase default value of max_fsm_relations
- Fix problem when fetching backwards in a cursor for a single-row query
- Make backward fetch work properly with cursor on SELECT DISTINCT query
- Fix problems with loading pg_dump files containing contrib/lo usage
- Fix problem with all-numeric user names
- Fix possible memory leak and core dump during disconnect in libpgtcl
- Make plpython's spi_execute command handle nulls properly (Andrew Bosma)
- Adjust plpython error reporting so that its regression test passes again
- Work with bison 1.875
- Handle mixed-case names properly in plpgsql's %type (Neil)
- Fix core dump in pltcl when executing a query rewritten by a rule
- Repair array subscript overruns (per report from Yichen Xie)
- Reduce MAX_TIME_PRECISION from 13 to 10 in floating-point case
- Correctly case-fold variable names in per-database and per-user settings
- Fix coredump in plpgsql's RETURN NEXT when SELECT into record returns no rows
- Fix outdated use of pg_type.typprtlen in python client interface
- Correctly handle fractional seconds in timestamps in JDBC driver
- Improve performance of getImportedKeys() in JDBC
- Make shared-library symlinks work standardly on HPUX (Giles)
- Repair inconsistent rounding behavior for timestamp, time, interval
- SSL negotiation fixes (Nathan Mueller)
- Make libpq's ~/.pgpass feature work when connecting with PQconnectDB
- Update my2pg, ora2pg
- Translation updates
- Add casts between types lo and oid in contrib/lo
- fastpath code now checks for privilege to call function

E.230. Release 7.3.1

Release Date: 2002-12-18

This release contains a variety of fixes for version 7.3.

E.230.1. Migration to Version 7.3.1

A dump/restore is *not* required for those running version 7.3. However, it should be noted that the main PostgreSQL interface library, libpq, has a new major version number for this release, which might require recompilation of client code in certain cases.

E.230.2. Changes

- Fix a core dump of COPY TO when client/server encodings don't match (Tom)
- Allow pg_dump to work with pre-7.2 servers (Philip)
- contrib/adddepend fixes (Tom)
- Fix problem with deletion of per-user/per-database config settings (Tom)
- contrib/vacuumlo fix (Tom)
- Allow 'password' encryption even when pg_shadow contains MD5 passwords (Bruce)
- contrib/dbmirror fix (Steven Singer)
- Optimizer fixes (Tom)
- contrib/tsearch fixes (Teodor Sigaev, Magnus)
- Allow locale names to be mixed case (Nicolai Tufar)
- Increment libpq library's major version number (Bruce)
- pg_hba.conf error reporting fixes (Bruce, Neil)
- Add SCO Openserver 5.0.4 as a supported platform (Bruce)
- Prevent EXPLAIN from crashing server (Tom)
- SSL fixes (Nathan Mueller)
- Prevent composite column creation via ALTER TABLE (Tom)

E.231. Release 7.3

Release Date: 2002-11-27

E.231.1. Overview

Major changes in this release:

Schemas

Schemas allow users to create objects in separate namespaces, so two people or applications can have tables with the same name. There is also a public schema for shared tables. Table/index creation can be restricted by removing privileges on the public schema.

Drop Column

PostgreSQL now supports the `ALTER TABLE ... DROP COLUMN` functionality.

Table Functions

Functions returning multiple rows and/or multiple columns are now much easier to use than before. You can call such a "table function" in the `SELECT FROM` clause, treating its output like a table. Also, PL/pgSQL functions can now return sets.

Prepared Queries

PostgreSQL now supports prepared queries, for improved performance.

Dependency Tracking

PostgreSQL now records object dependencies, which allows improvements in many areas. `DROP` statements now take either `CASCADE` or `RESTRICT` to control whether dependent objects are also dropped.

Privileges

Functions and procedural languages now have privileges, and functions can be defined to run with the privileges of their creator.

Internationalization

Both multibyte and locale support are now always enabled.

Logging

A variety of logging options have been enhanced.

Interfaces

A large number of interfaces have been moved to http://gborg.postgresql.org where they can be developed and released independently.

Functions/Identifiers

By default, functions can now take up to 32 parameters, and identifiers can be up to 63 bytes long. Also, `OPAQUE` is now deprecated: there are specific "pseudo-datatypes" to represent each of the former meanings of `OPAQUE` in function argument and result types.

E.231.2. Migration to Version 7.3

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release. If your application examines the system catalogs, additional changes will be required due to the introduction of schemas in 7.3; for more information, see: http://developer.postgresql.org/~momjian/upgrade_tips_7.3.

Observe the following incompatibilities:

- Pre-6.3 clients are no longer supported.
- `pg_hba.conf` now has a column for the user name and additional features. Existing files need to be adjusted.

- Several `postgresql.conf` logging parameters have been renamed.
- `LIMIT #,#` has been disabled; use `LIMIT # OFFSET #`.
- `INSERT` statements with column lists must specify a value for each specified column. For example, `INSERT INTO tab (col1, col2) VALUES ('val1')` is now invalid. It's still allowed to supply fewer columns than expected if the `INSERT` does not have a column list.
- `serial` columns are no longer automatically `UNIQUE`; thus, an index will not automatically be created.
- A `SET` command inside an aborted transaction is now rolled back.
- `COPY` no longer considers missing trailing columns to be null. All columns need to be specified. (However, one can achieve a similar effect by specifying a column list in the `COPY` command.)
- The data type `timestamp` is now equivalent to `timestamp without time zone`, instead of `timestamp with time zone`.
- Pre-7.3 databases loaded into 7.3 will not have the new object dependencies for `serial` columns, unique constraints, and foreign keys. See the directory `contrib/adddepend/` for a detailed description and a script that will add such dependencies.
- An empty string (″) is no longer allowed as the input into an integer field. Formerly, it was silently interpreted as 0.

E.231.3. Changes

E.231.3.1. Server Operation

- Add pg_locks view to show locks (Neil)
- Security fixes for password negotiation memory allocation (Neil)
- Remove support for version 0 FE/BE protocol (PostgreSQL 6.2 and earlier) (Tom)
- Reserve the last few backend slots for superusers, add parameter superuser_reserved_connections to control this (Nigel J. Andrews)

E.231.3.2. Performance

- Improve startup by calling localtime() only once (Tom)
- Cache system catalog information in flat files for faster startup (Tom)
- Improve caching of index information (Tom)
- Optimizer improvements (Tom, Fernando Nasser)
- Catalog caches now store failed lookups (Tom)
- Hash function improvements (Neil)
- Improve performance of query tokenization and network handling (Peter)
- Speed improvement for large object restore (Mario Weilguni)
- Mark expired index entries on first lookup, saving later heap fetches (Tom)
- Avoid excessive NULL bitmap padding (Manfred Koizar)

- Add BSD-licensed qsort() for Solaris, for performance (Bruce)
- Reduce per-row overhead by four bytes (Manfred Koizar)
- Fix GEQO optimizer bug (Neil Conway)
- Make WITHOUT OID actually save four bytes per row (Manfred Koizar)
- Add default_statistics_target variable to specify ANALYZE buckets (Neil)
- Use local buffer cache for temporary tables so no WAL overhead (Tom)
- Improve free space map performance on large tables (Stephen Marshall, Tom)
- Improved WAL write concurrency (Tom)

E.231.3.3. Privileges

- Add privileges on functions and procedural languages (Peter)
- Add OWNER to CREATE DATABASE so superusers can create databases on behalf of unprivileged users (Gavin Sherry, Tom)
- Add new object privilege bits EXECUTE and USAGE (Tom)
- Add SET SESSION AUTHORIZATION DEFAULT and RESET SESSION AUTHORIZATION (Tom)
- Allow functions to be executed with the privilege of the function owner (Peter)

E.231.3.4. Server Configuration

- Server log messages now tagged with LOG, not DEBUG (Bruce)
- Add user column to pg_hba.conf (Bruce)
- Have log_connections output two lines in log file (Tom)
- Remove debug_level from postgresql.conf, now server_min_messages (Bruce)
- New ALTER DATABASE/USER ... SET command for per-user/database initialization (Peter)
- New parameters server_min_messages and client_min_messages to control which messages are sent to the server logs or client applications (Bruce)
- Allow pg_hba.conf to specify lists of users/databases separated by commas, group names prepended with +, and file names prepended with @ (Bruce)
- Remove secondary password file capability and pg_password utility (Bruce)
- Add variable db_user_namespace for database-local user names (Bruce)
- SSL improvements (Bear Giles)
- Make encryption of stored passwords the default (Bruce)
- Allow pg_statistics to be reset by calling pg_stat_reset() (Christopher)
- Add log_duration parameter (Bruce)
- Rename debug_print_query to log_statement (Bruce)
- Rename show_query_stats to show_statement_stats (Bruce)
- Add param log_min_error_statement to print commands to logs on error (Gavin)

E.231.3.5. Queries

- Make cursors insensitive, meaning their contents do not change (Tom)
- Disable LIMIT #,# syntax; now only LIMIT # OFFSET # supported (Bruce)
- Increase identifier length to 63 (Neil, Bruce)
- UNION fixes for merging >= 3 columns of different lengths (Tom)
- Add DEFAULT key word to INSERT, e.g., INSERT ... (..., DEFAULT, ...) (Rod)
- Allow views to have default values using ALTER COLUMN ... SET DEFAULT (Neil)
- Fail on INSERTs with column lists that don't supply all column values, e.g., INSERT INTO tab (col1, col2) VALUES ('val1'); (Rod)
- Fix for join aliases (Tom)
- Fix for FULL OUTER JOINs (Tom)
- Improve reporting of invalid identifier and location (Tom, Gavin)
- Fix OPEN cursor(args) (Tom)
- Allow 'ctid' to be used in a view and currtid(viewname) (Hiroshi)
- Fix for CREATE TABLE AS with UNION (Tom)
- SQL99 syntax improvements (Thomas)
- Add statement_timeout variable to cancel queries (Bruce)
- Allow prepared queries with PREPARE/EXECUTE (Neil)
- Allow FOR UPDATE to appear after LIMIT/OFFSET (Bruce)
- Add variable autocommit (Tom, David Van Wie)

E.231.3.6. Object Manipulation

- Make equals signs optional in CREATE DATABASE (Gavin Sherry)
- Make ALTER TABLE OWNER change index ownership too (Neil)
- New ALTER TABLE tabname ALTER COLUMN colname SET STORAGE controls TOAST storage, compression (John Gray)
- Add schema support, CREATE/DROP SCHEMA (Tom)
- Create schema for temporary tables (Tom)
- Add variable search_path for schema search (Tom)
- Add ALTER TABLE SET/DROP NOT NULL (Christopher)
- New CREATE FUNCTION volatility levels (Tom)
- Make rule names unique only per table (Tom)
- Add 'ON tablename' clause to DROP RULE and COMMENT ON RULE (Tom)
- Add ALTER TRIGGER RENAME (Joe)
- New current_schema() and current_schemas() inquiry functions (Tom)
- Allow functions to return multiple rows (table functions) (Joe)

- Make WITH optional in CREATE DATABASE, for consistency (Bruce)
- Add object dependency tracking (Rod, Tom)
- Add RESTRICT/CASCADE to DROP commands (Rod)
- Add ALTER TABLE DROP for non-CHECK CONSTRAINT (Rod)
- Autodestroy sequence on DROP of table with SERIAL (Rod)
- Prevent column dropping if column is used by foreign key (Rod)
- Automatically drop constraints/functions when object is dropped (Rod)
- Add CREATE/DROP OPERATOR CLASS (Bill Studenmund, Tom)
- Add ALTER TABLE DROP COLUMN (Christopher, Tom, Hiroshi)
- Prevent inherited columns from being removed or renamed (Alvaro Herrera)
- Fix foreign key constraints to not error on intermediate database states (Stephan)
- Propagate column or table renaming to foreign key constraints
- Add CREATE OR REPLACE VIEW (Gavin, Neil, Tom)
- Add CREATE OR REPLACE RULE (Gavin, Neil, Tom)
- Have rules execute alphabetically, returning more predictable values (Tom)
- Triggers are now fired in alphabetical order (Tom)
- Add /contrib/adddepend to handle pre-7.3 object dependencies (Rod)
- Allow better casting when inserting/updating values (Tom)

E.231.3.7. Utility Commands

- Have COPY TO output embedded carriage returns and newlines as \r and \n (Tom)
- Allow DELIMITER in COPY FROM to be 8-bit clean (Tatsuo)
- Make pg_dump use ALTER TABLE ADD PRIMARY KEY, for performance (Neil)
- Disable brackets in multistatement rules (Bruce)
- Disable VACUUM from being called inside a function (Bruce)
- Allow dropdb and other scripts to use identifiers with spaces (Bruce)
- Restrict database comment changes to the current database
- Allow comments on operators, independent of the underlying function (Rod)
- Rollback SET commands in aborted transactions (Tom)
- EXPLAIN now outputs as a query (Tom)
- Display condition expressions and sort keys in EXPLAIN (Tom)
- Add 'SET LOCAL var = value' to set configuration variables for a single transaction (Tom)
- Allow ANALYZE to run in a transaction (Bruce)
- Improve COPY syntax using new WITH clauses, keep backward compatibility (Bruce)
- Fix pg_dump to consistently output tags in non-ASCII dumps (Bruce)
- Make foreign key constraints clearer in dump file (Rod)

- Add COMMENT ON CONSTRAINT (Rod)
- Allow COPY TO/FROM to specify column names (Brent Verner)
- Dump UNIQUE and PRIMARY KEY constraints as ALTER TABLE (Rod)
- Have SHOW output a query result (Joe)
- Generate failure on short COPY lines rather than pad NULLs (Neil)
- Fix CLUSTER to preserve all table attributes (Alvaro Herrera)
- New pg_settings table to view/modify GUC settings (Joe)
- Add smart quoting, portability improvements to pg_dump output (Peter)
- Dump serial columns out as SERIAL (Tom)
- Enable large file support, >2G for pg_dump (Peter, Philip Warner, Bruce)
- Disallow TRUNCATE on tables that are involved in referential constraints (Rod)
- Have TRUNCATE also auto-truncate the toast table of the relation (Tom)
- Add clusterdb utility that will auto-cluster an entire database based on previous CLUSTER operations (Alvaro Herrera)
- Overhaul pg_dumpall (Peter)
- Allow REINDEX of TOAST tables (Tom)
- Implemented START TRANSACTION, per SQL99 (Neil)
- Fix rare index corruption when a page split affects bulk delete (Tom)
- Fix ALTER TABLE ... ADD COLUMN for inheritance (Alvaro Herrera)

E.231.3.8. Data Types and Functions

- Fix factorial(0) to return 1 (Bruce)
- Date/time/timezone improvements (Thomas)
- Fix for array slice extraction (Tom)
- Fix extract/date_part to report proper microseconds for timestamp (Tatsuo)
- Allow text_substr() and bytea_substr() to read TOAST values more efficiently (John Gray)
- Add domain support (Rod)
- Make WITHOUT TIME ZONE the default for TIMESTAMP and TIME data types (Thomas)
- Allow alternate storage scheme of 64-bit integers for date/time types using --enable-integer-datetimes in configure (Thomas)
- Make timezone(timestamptz) return timestamp rather than a string (Thomas)
- Allow fractional seconds in date/time types for dates prior to 1BC (Thomas)
- Limit timestamp data types to 6 decimal places of precision (Thomas)
- Change timezone conversion functions from timetz() to timezone() (Thomas)
- Add configuration variables datestyle and timezone (Tom)
- Add OVERLAY(), which allows substitution of a substring in a string (Thomas)
- Add SIMILAR TO (Thomas, Tom)

- Add regular expression SUBSTRING(string FROM pat FOR escape) (Thomas)
- Add LOCALTIME and LOCALTIMESTAMP functions (Thomas)
- Add named composite types using CREATE TYPE typename AS (column) (Joe)
- Allow composite type definition in the table alias clause (Joe)
- Add new API to simplify creation of C language table functions (Joe)
- Remove ODBC-compatible empty parentheses from calls to SQL99 functions for which these parentheses do not match the standard (Thomas)
- Allow macaddr data type to accept 12 hex digits with no separators (Mike Wyer)
- Add CREATE/DROP CAST (Peter)
- Add IS DISTINCT FROM operator (Thomas)
- Add SQL99 TREAT() function, synonym for CAST() (Thomas)
- Add pg_backend_pid() to output backend pid (Bruce)
- Add IS OF / IS NOT OF type predicate (Thomas)
- Allow bit string constants without fully-specified length (Thomas)
- Allow conversion between 8-byte integers and bit strings (Thomas)
- Implement hex literal conversion to bit string literal (Thomas)
- Allow table functions to appear in the FROM clause (Joe)
- Increase maximum number of function parameters to 32 (Bruce)
- No longer automatically create index for SERIAL column (Tom)
- Add current_database() (Rod)
- Fix cash_words() to not overflow buffer (Tom)
- Add functions replace(), split_part(), to_hex() (Joe)
- Fix LIKE for bytea as a right-hand argument (Joe)
- Prevent crashes caused by SELECT cash_out(2) (Tom)
- Fix to_char(1,'FM999.99') to return a period (Karel)
- Fix trigger/type/language functions returning OPAQUE to return proper type (Tom)

E.231.3.9. Internationalization

- Add additional encodings: Korean (JOHAB), Thai (WIN874), Vietnamese (TCVN), Arabic (WIN1256), Simplified Chinese (GBK), Korean (UHC) (Eiji Tokuya)
- Enable locale support by default (Peter)
- Add locale variables (Peter)
- Escape byes >= 0x7f for multibyte in PQescapeBytea/PQunescapeBytea (Tatsuo)
- Add locale awareness to regular expression character classes
- Enable multibyte support by default (Tatsuo)
- Add GB18030 multibyte support (Bill Huang)
- Add CREATE/DROP CONVERSION, allowing loadable encodings (Tatsuo, Kaori)

- Add pg_conversion table (Tatsuo)
- Add SQL99 CONVERT() function (Tatsuo)
- pg_dumpall, pg_controldata, and pg_resetxlog now national-language aware (Peter)
- New and updated translations

E.231.3.10. Server-side Languages

- Allow recursive SQL function (Peter)
- Change PL/Tcl build to use configured compiler and Makefile.shlib (Peter)
- Overhaul the PL/pgSQL FOUND variable to be more Oracle-compatible (Neil, Tom)
- Allow PL/pgSQL to handle quoted identifiers (Tom)
- Allow set-returning PL/pgSQL functions (Neil)
- Make PL/pgSQL schema-aware (Joe)
- Remove some memory leaks (Nigel J. Andrews, Tom)

E.231.3.11. psql

- Don't lowercase psql \connect database name for 7.2.0 compatibility (Tom)
- Add psql \timing to time user queries (Greg Sabino Mullane)
- Have psql \d show index information (Greg Sabino Mullane)
- New psql \dD shows domains (Jonathan Eisler)
- Allow psql to show rules on views (Paul ?)
- Fix for psql variable substitution (Tom)
- Allow psql \d to show temporary table structure (Tom)
- Allow psql \d to show foreign keys (Rod)
- Fix \? to honor \pset pager (Bruce)
- Have psql reports its version number on startup (Tom)
- Allow \copy to specify column names (Tom)

E.231.3.12. libpq

- Add ~/.pgpass to store host/user password combinations (Alvaro Herrera)
- Add PQunescapeBytea() function to libpq (Patrick Welche)
- Fix for sending large queries over non-blocking connections (Bernhard Herzog)
- Fix for libpq using timers on Win9X (David Ford)
- Allow libpq notify to handle servers with different-length identifiers (Tom)
- Add libpq PQescapeString() and PQescapeBytea() to Windows (Bruce)

- Fix for SSL with non-blocking connections (Jack Bates)
- Add libpq connection timeout parameter (Denis A Ustimenko)

E.231.3.13. JDBC

- Allow JDBC to compile with JDK 1.4 (Dave)
- Add JDBC 3 support (Barry)
- Allows JDBC to set loglevel by adding ?loglevel=X to the connection URL (Barry)
- Add Driver.info() message that prints out the version number (Barry)
- Add updateable result sets (Raghu Nidagal, Dave)
- Add support for callable statements (Paul Bethe)
- Add query cancel capability
- Add refresh row (Dave)
- Fix MD5 encryption handling for multibyte servers (Jun Kawai)
- Add support for prepared statements (Barry)

E.231.3.14. Miscellaneous Interfaces

- Fixed ECPG bug concerning octal numbers in single quotes (Michael)
- Move src/interfaces/libpgeasy to http://gborg.postgresql.org (Marc, Bruce)
- Improve Python interface (Elliot Lee, Andrew Johnson, Greg Copeland)
- Add libpgtcl connection close event (Gerhard Hintermayer)
- Move src/interfaces/libpq++ to http://gborg.postgresql.org (Marc, Bruce)
- Move src/interfaces/odbc to http://gborg.postgresql.org (Marc)
- Move src/interfaces/libpgeasy to http://gborg.postgresql.org (Marc, Bruce)
- Move src/interfaces/perl5 to http://gborg.postgresql.org (Marc, Bruce)
- Remove src/bin/pgaccess from main tree, now at http://www.pgaccess.org (Bruce)
- Add pg_on_connection_loss command to libpgtcl (Gerhard Hintermayer, Tom)

E.231.3.15. Source Code

- Fix for parallel make (Peter)
- AIX fixes for linking Tcl (Andreas Zeugswetter)
- Allow PL/Perl to build under Cygwin (Jason Tishler)
- Improve MIPS compiles (Peter, Oliver Elphick)
- Require Autoconf version 2.53 (Peter)
- Require readline and zlib by default in configure (Peter)

- Allow Solaris to use Intimate Shared Memory (ISM), for performance (Scott Brunza, P.J. Josh Rovero)
- Always enable syslog in compile, remove --enable-syslog option (Tatsuo)
- Always enable multibyte in compile, remove --enable-multibyte option (Tatsuo)
- Always enable locale in compile, remove --enable-locale option (Peter)
- Fix for Win9x DLL creation (Magnus Naeslund)
- Fix for link() usage by WAL code on Windows, BeOS (Jason Tishler)
- Add sys/types.h to c.h, remove from main files (Peter, Bruce)
- Fix AIX hang on SMP machines (Tomoyuki Niijima)
- AIX SMP hang fix (Tomoyuki Niijima)
- Fix pre-1970 date handling on newer glibc libraries (Tom)
- Fix PowerPC SMP locking (Tom)
- Prevent gcc -ffast-math from being used (Peter, Tom)
- Bison >= 1.50 now required for developer builds
- Kerberos 5 support now builds with Heimdal (Peter)
- Add appendix in the User's Guide which lists SQL features (Thomas)
- Improve loadable module linking to use RTLD_NOW (Tom)
- New error levels WARNING, INFO, LOG, DEBUG[1-5] (Bruce)
- New src/port directory holds replaced libc functions (Peter, Bruce)
- New pg_namespace system catalog for schemas (Tom)
- Add pg_class.relnamespace for schemas (Tom)
- Add pg_type.typnamespace for schemas (Tom)
- Add pg_proc.pronamespace for schemas (Tom)
- Restructure aggregates to have pg_proc entries (Tom)
- System relations now have their own namespace, pg_* test not required (Fernando Nasser)
- Rename TOAST index names to be *_index rather than *_idx (Neil)
- Add namespaces for operators, opclasses (Tom)
- Add additional checks to server control file (Thomas)
- New Polish FAQ (Marcin Mazurek)
- Add Posix semaphore support (Tom)
- Document need for reindex (Bruce)
- Rename some internal identifiers to simplify Windows compile (Jan, Katherine Ward)
- Add documentation on computing disk space (Bruce)
- Remove KSQO from GUC (Bruce)
- Fix memory leak in rtree (Kenneth Been)
- Modify a few error messages for consistency (Bruce)
- Remove unused system table columns (Peter)
- Make system columns NOT NULL where appropriate (Tom)

- Clean up use of sprintf in favor of snprintf() (Neil, Jukka Holappa)
- Remove OPAQUE and create specific subtypes (Tom)
- Cleanups in array internal handling (Joe, Tom)
- Disallow pg_atoi(”) (Bruce)
- Remove parameter wal_files because WAL files are now recycled (Bruce)
- Add version numbers to heap pages (Tom)

E.231.3.16. Contrib

- Allow inet arrays in /contrib/array (Neil)
- GiST fixes (Teodor Sigaev, Neil)
- Upgrade /contrib/mysql
- Add /contrib/dbsize which shows table sizes without vacuum (Peter)
- Add /contrib/intagg, integer aggregator routines (mlw)
- Improve /contrib/oid2name (Neil, Bruce)
- Improve /contrib/tsearch (Oleg, Teodor Sigaev)
- Cleanups of /contrib/rserver (Alexey V. Borzov)
- Update /contrib/oracle conversion utility (Gilles Darold)
- Update /contrib/dblink (Joe)
- Improve options supported by /contrib/vacuumlo (Mario Weilguni)
- Improvements to /contrib/intarray (Oleg, Teodor Sigaev, Andrey Oktyabrski)
- Add /contrib/reindexdb utility (Shaun Thomas)
- Add indexing to /contrib/isbn_issn (Dan Weston)
- Add /contrib/dbmirror (Steven Singer)
- Improve /contrib/pgbench (Neil)
- Add /contrib/tablefunc table function examples (Joe)
- Add /contrib/ltree data type for tree structures (Teodor Sigaev, Oleg Bartunov)
- Move /contrib/pg_controldata, pg_resetxlog into main tree (Bruce)
- Fixes to /contrib/cube (Bruno Wolff)
- Improve /contrib/fulltextindex (Christopher)

E.232. Release 7.2.8

Release Date: 2005-05-09

This release contains a variety of fixes from 7.2.7, including one security-related issue.

E.232.1. Migration to Version 7.2.8

A dump/restore is not required for those running 7.2.X.

E.232.2. Changes

- Repair ancient race condition that allowed a transaction to be seen as committed for some purposes (eg SELECT FOR UPDATE) slightly sooner than for other purposes

  This is an extremely serious bug since it could lead to apparent data inconsistencies being briefly visible to applications.

- Repair race condition between relation extension and VACUUM

  This could theoretically have caused loss of a page's worth of freshly-inserted data, although the scenario seems of very low probability. There are no known cases of it having caused more than an Assert failure.

- Fix `EXTRACT(EPOCH)` for `TIME WITH TIME ZONE` values
- Additional buffer overrun checks in plpgsql (Neil)
- Fix pg_dump to dump index names and trigger names containing `%` correctly (Neil)
- Prevent `to_char(interval)` from dumping core for month-related formats
- Fix `contrib/pgcrypto` for newer OpenSSL builds (Marko Kreen)

E.233. Release 7.2.7

Release Date: 2005-01-31

This release contains a variety of fixes from 7.2.6, including several security-related issues.

E.233.1. Migration to Version 7.2.7

A dump/restore is not required for those running 7.2.X.

E.233.2. Changes

- Disallow `LOAD` to non-superusers

  On platforms that will automatically execute initialization functions of a shared library (this includes at least Windows and ELF-based Unixen), `LOAD` can be used to make the server execute arbitrary code. Thanks to NGS Software for reporting this.

- Add needed STRICT marking to some contrib functions (Kris Jurka)
- Avoid buffer overrun when plpgsql cursor declaration has too many parameters (Neil)

- Fix planning error for FULL and RIGHT outer joins

  The result of the join was mistakenly supposed to be sorted the same as the left input. This could not only deliver mis-sorted output to the user, but in case of nested merge joins could give outright wrong answers.

- Fix display of negative intervals in SQL and GERMAN datestyles

E.234. Release 7.2.6

Release Date: 2004-10-22

This release contains a variety of fixes from 7.2.5.

E.234.1. Migration to Version 7.2.6

A dump/restore is not required for those running 7.2.X.

E.234.2. Changes

- Repair possible failure to update hint bits on disk

  Under rare circumstances this oversight could lead to "could not access transaction status" failures, which qualifies it as a potential-data-loss bug.

- Ensure that hashed outer join does not miss tuples

  Very large left joins using a hash join plan could fail to output unmatched left-side rows given just the right data distribution.

- Disallow running pg_ctl as root

  This is to guard against any possible security issues.

- Avoid using temp files in /tmp in make_oidjoins_check

  This has been reported as a security issue, though it's hardly worthy of concern since there is no reason for non-developers to use this script anyway.

- Update to newer versions of Bison

E.235. Release 7.2.5

Release Date: 2004-08-16

This release contains a variety of fixes from 7.2.4.

E.235.1. Migration to Version 7.2.5

A dump/restore is not required for those running 7.2.X.

E.235.2. Changes

- Prevent possible loss of committed transactions during crash

  Due to insufficient interlocking between transaction commit and checkpointing, it was possible for transactions committed just before the most recent checkpoint to be lost, in whole or in part, following a database crash and restart. This is a serious bug that has existed since PostgreSQL 7.1.
- Fix corner case for btree search in parallel with first root page split
- Fix buffer overrun in `to_ascii` (Guido Notari)
- Fix core dump in deadlock detection on machines where char is unsigned
- Fix failure to respond to `pg_ctl stop -m fast` after Async_NotifyHandler runs
- Repair memory leaks in pg_dump
- Avoid conflict with system definition of `isblank()` function or macro

E.236. Release 7.2.4

Release Date: 2003-01-30

This release contains a variety of fixes for version 7.2.3, including fixes to prevent possible data loss.

E.236.1. Migration to Version 7.2.4

A dump/restore is *not* required for those running version 7.2.*.

E.236.2. Changes

- Fix some additional cases of VACUUM "No one parent tuple was found" error
- Prevent VACUUM from being called inside a function (Bruce)
- Ensure pg_clog updates are sync'd to disk before marking checkpoint complete
- Avoid integer overflow during large hash joins
- Make GROUP commands work when pg_group.grolist is large enough to be toasted
- Fix errors in datetime tables; some timezone names weren't being recognized
- Fix integer overflows in circle_poly(), path_encode(), path_add() (Neil)
- Repair long-standing logic errors in lseg_eq(), lseg_ne(), lseg_center()

E.237. Release 7.2.3

Release Date: 2002-10-01

This release contains a variety of fixes for version 7.2.2, including fixes to prevent possible data loss.

E.237.1. Migration to Version 7.2.3

A dump/restore is *not* required for those running version 7.2.*.

E.237.2. Changes

- Prevent possible compressed transaction log loss (Tom)
- Prevent non-superuser from increasing most recent vacuum info (Tom)
- Handle pre-1970 date values in newer versions of glibc (Tom)
- Fix possible hang during server shutdown
- Prevent spinlock hangs on SMP PPC machines (Tomoyuki Niijima)
- Fix pg_dump to properly dump FULL JOIN USING (Tom)

E.238. Release 7.2.2

Release Date: 2002-08-23

This release contains a variety of fixes for version 7.2.1.

E.238.1. Migration to Version 7.2.2

A dump/restore is *not* required for those running version 7.2.*.

E.238.2. Changes

- Allow EXECUTE of "CREATE TABLE AS ... SELECT" in PL/pgSQL (Tom)
- Fix for compressed transaction log id wraparound (Tom)
- Fix PQescapeBytea/PQunescapeBytea so that they handle bytes > 0x7f (Tatsuo)
- Fix for psql and pg_dump crashing when invoked with non-existent long options (Tatsuo)
- Fix crash when invoking geometric operators (Tom)
- Allow OPEN cursor(args) (Tom)

- Fix for rtree_gist index build (Teodor)
- Fix for dumping user-defined aggregates (Tom)
- contrib/intarray fixes (Oleg)
- Fix for complex UNION/EXCEPT/INTERSECT queries using parens (Tom)
- Fix to pg_convert (Tatsuo)
- Fix for crash with long DATA strings (Thomas, Neil)
- Fix for repeat(), lpad(), rpad() and long strings (Neil)

E.239. Release 7.2.1

Release Date: 2002-03-21

This release contains a variety of fixes for version 7.2.

E.239.1. Migration to Version 7.2.1

A dump/restore is *not* required for those running version 7.2.

E.239.2. Changes

- Ensure that sequence counters do not go backwards after a crash (Tom)
- Fix pgaccess kanji-conversion key binding (Tatsuo)
- Optimizer improvements (Tom)
- Cash I/O improvements (Tom)
- New Russian FAQ
- Compile fix for missing AuthBlockSig (Heiko)
- Additional time zones and time zone fixes (Thomas)
- Allow psql \connect to handle mixed case database and user names (Tom)
- Return proper OID on command completion even with ON INSERT rules (Tom)
- Allow COPY FROM to use 8-bit DELIMITERS (Tatsuo)
- Fix bug in extract/date_part for milliseconds/microseconds (Tatsuo)
- Improve handling of multiple UNIONs with different lengths (Tom)
- contrib/btree_gist improvements (Teodor Sigaev)
- contrib/tsearch dictionary improvements, see README.tsearch for an additional installation step (Thomas T. Thai, Teodor Sigaev)
- Fix for array subscripts handling (Tom)
- Allow EXECUTE of "CREATE TABLE AS ... SELECT" in PL/pgSQL (Tom)

E.240. Release 7.2

Release Date: 2002-02-04

E.240.1. Overview

This release improves PostgreSQL for use in high-volume applications.

Major changes in this release:

VACUUM

Vacuuming no longer locks tables, thus allowing normal user access during the vacuum. A new `VACUUM FULL` command does old-style vacuum by locking the table and shrinking the on-disk copy of the table.

Transactions

There is no longer a problem with installations that exceed four billion transactions.

OIDs

OIDs are now optional. Users can now create tables without OIDs for cases where OID usage is excessive.

Optimizer

The system now computes histogram column statistics during `ANALYZE`, allowing much better optimizer choices.

Security

A new MD5 encryption option allows more secure storage and transfer of passwords. A new Unix-domain socket authentication option is available on Linux and BSD systems.

Statistics

Administrators can use the new table access statistics module to get fine-grained information about table and index usage.

Internationalization

Program and library messages can now be displayed in several languages.

E.240.2. Migration to Version 7.2

A dump/restore using `pg_dump` is required for those wishing to migrate data from any previous release.

Observe the following incompatibilities:

- The semantics of the `VACUUM` command have changed in this release. You might wish to update your maintenance procedures accordingly.
- In this release, comparisons using `= NULL` will always return false (or NULL, more precisely). Previous releases automatically transformed this syntax to `IS NULL`. The old behavior can be re-enabled using a `postgresql.conf` parameter.

- The `pg_hba.conf` and `pg_ident.conf` configuration is now only reloaded after receiving a SIGHUP signal, not with each connection.
- The function `octet_length()` now returns the uncompressed data length.
- The date/time value `'current'` is no longer available. You will need to rewrite your applications.
- The `timestamp()`, `time()`, and `interval()` functions are no longer available. Instead of `timestamp()`, use `timestamp 'string'` or `CAST`.

The `SELECT ... LIMIT #,#` syntax will be removed in the next release. You should change your queries to use separate LIMIT and OFFSET clauses, e.g. `LIMIT 10 OFFSET 20`.

E.240.3. Changes

E.240.3.1. Server Operation

- Create temporary files in a separate directory (Bruce)
- Delete orphaned temporary files on postmaster startup (Bruce)
- Added unique indexes to some system tables (Tom)
- System table operator reorganization (Oleg Bartunov, Teodor Sigaev, Tom)
- Renamed pg_log to pg_clog (Tom)
- Enable SIGTERM, SIGQUIT to kill backends (Jan)
- Removed compile-time limit on number of backends (Tom)
- Better cleanup for semaphore resource failure (Tatsuo, Tom)
- Allow safe transaction ID wraparound (Tom)
- Removed OIDs from some system tables (Tom)
- Removed "triggered data change violation" error check (Tom)
- SPI portal creation of prepared/saved plans (Jan)
- Allow SPI column functions to work for system columns (Tom)
- Long value compression improvement (Tom)
- Statistics collector for table, index access (Jan)
- Truncate extra-long sequence names to a reasonable value (Tom)
- Measure transaction times in milliseconds (Thomas)
- Fix TID sequential scans (Hiroshi)
- Superuser ID now fixed at 1 (Peter E)
- New pg_ctl "reload" option (Tom)

E.240.3.2. Performance

- Optimizer improvements (Tom)
- New histogram column statistics for optimizer (Tom)

- Reuse write-ahead log files rather than discarding them (Tom)
- Cache improvements (Tom)
- IS NULL, IS NOT NULL optimizer improvement (Tom)
- Improve lock manager to reduce lock contention (Tom)
- Keep relcache entries for index access support functions (Tom)
- Allow better selectivity with NaN and infinities in NUMERIC (Tom)
- R-tree performance improvements (Kenneth Been)
- B-tree splits more efficient (Tom)

E.240.3.3. Privileges

- Change UPDATE, DELETE privileges to be distinct (Peter E)
- New REFERENCES, TRIGGER privileges (Peter E)
- Allow GRANT/REVOKE to/from more than one user at a time (Peter E)
- New has_table_privilege() function (Joe Conway)
- Allow non-superuser to vacuum database (Tom)
- New SET SESSION AUTHORIZATION command (Peter E)
- Fix bug in privilege modifications on newly created tables (Tom)
- Disallow access to pg_statistic for non-superuser, add user-accessible views (Tom)

E.240.3.4. Client Authentication

- Fork postmaster before doing authentication to prevent hangs (Peter E)
- Add ident authentication over Unix domain sockets on Linux, *BSD (Helge Bahmann, Oliver Elphick, Teodor Sigaev, Bruce)
- Add a password authentication method that uses MD5 encryption (Bruce)
- Allow encryption of stored passwords using MD5 (Bruce)
- PAM authentication (Dominic J. Eidson)
- Load pg_hba.conf and pg_ident.conf only on startup and SIGHUP (Bruce)

E.240.3.5. Server Configuration

- Interpretation of some time zone abbreviations as Australian rather than North American now settable at run time (Bruce)
- New parameter to set default transaction isolation level (Peter E)
- New parameter to enable conversion of "expr = NULL" into "expr IS NULL", off by default (Peter E)
- New parameter to control memory usage by VACUUM (Tom)

- New parameter to set client authentication timeout (Tom)
- New parameter to set maximum number of open files (Tom)

E.240.3.6. Queries

- Statements added by INSERT rules now execute after the INSERT (Jan)
- Prevent unadorned relation names in target list (Bruce)
- NULLs now sort after all normal values in ORDER BY (Tom)
- New IS UNKNOWN, IS NOT UNKNOWN Boolean tests (Tom)
- New SHARE UPDATE EXCLUSIVE lock mode (Tom)
- New EXPLAIN ANALYZE command that shows run times and row counts (Martijn van Oosterhout)
- Fix problem with LIMIT and subqueries (Tom)
- Fix for LIMIT, DISTINCT ON pushed into subqueries (Tom)
- Fix nested EXCEPT/INTERSECT (Tom)

E.240.3.7. Schema Manipulation

- Fix SERIAL in temporary tables (Bruce)
- Allow temporary sequences (Bruce)
- Sequences now use int8 internally (Tom)
- New SERIAL8 creates int8 columns with sequences, default still SERIAL4 (Tom)
- Make OIDs optional using WITHOUT OIDS (Tom)
- Add %TYPE syntax to CREATE TYPE (Ian Lance Taylor)
- Add ALTER TABLE / DROP CONSTRAINT for CHECK constraints (Christopher Kings-Lynne)
- New CREATE OR REPLACE FUNCTION to alter existing function (preserving the function OID) (Gavin Sherry)
- Add ALTER TABLE / ADD [UNIQUE | PRIMARY] (Christopher Kings-Lynne)
- Allow column renaming in views
- Make ALTER TABLE / RENAME COLUMN update column names of indexes (Brent Verner)
- Fix for ALTER TABLE / ADD CONSTRAINT ... CHECK with inherited tables (Stephan Szabo)
- ALTER TABLE RENAME update foreign-key trigger arguments correctly (Brent Verner)
- DROP AGGREGATE and COMMENT ON AGGREGATE now accept an aggtype (Tom)
- Add automatic return type data casting for SQL functions (Tom)
- Allow GiST indexes to handle NULLs and multikey indexes (Oleg Bartunov, Teodor Sigaev, Tom)
- Enable partial indexes (Martijn van Oosterhout)

E.240.3.8. Utility Commands

- Add RESET ALL, SHOW ALL (Marko Kreen)
- CREATE/ALTER USER/GROUP now allow options in any order (Vince)
- Add LOCK A, B, C functionality (Neil Padgett)
- New ENCRYPTED/UNENCRYPTED option to CREATE/ALTER USER (Bruce)
- New light-weight VACUUM does not lock table; old semantics are available as VACUUM FULL (Tom)
- Disable COPY TO/FROM on views (Bruce)
- COPY DELIMITERS string must be exactly one character (Tom)
- VACUUM warning about index tuples fewer than heap now only appears when appropriate (Martijn van Oosterhout)
- Fix privilege checks for CREATE INDEX (Tom)
- Disallow inappropriate use of CREATE/DROP INDEX/TRIGGER/VIEW (Tom)

E.240.3.9. Data Types and Functions

- SUM(), AVG(), COUNT() now uses int8 internally for speed (Tom)
- Add convert(), convert2() (Tatsuo)
- New function bit_length() (Peter E)
- Make the "n" in CHAR(n)/VARCHAR(n) represents letters, not bytes (Tatsuo)
- CHAR(), VARCHAR() now reject strings that are too long (Peter E)
- BIT VARYING now rejects bit strings that are too long (Peter E)
- BIT now rejects bit strings that do not match declared size (Peter E)
- INET, CIDR text conversion functions (Alex Pilosov)
- INET, CIDR operators << and <<= indexable (Alex Pilosov)
- Bytea \### now requires valid three digit octal number
- Bytea comparison improvements, now supports =, <>, >, >=, <, and <=
- Bytea now supports B-tree indexes
- Bytea now supports LIKE, LIKE...ESCAPE, NOT LIKE, NOT LIKE...ESCAPE
- Bytea now supports concatenation
- New bytea functions: position, substring, trim, btrim, and length
- New encode() function mode, "escaped", converts minimally escaped bytea to/from text
- Add pg_database_encoding_max_length() (Tatsuo)
- Add pg_client_encoding() function (Tatsuo)
- now() returns time with millisecond precision (Thomas)
- New TIMESTAMP WITHOUT TIMEZONE data type (Thomas)
- Add ISO date/time specification with "T", yyyy-mm-ddThh:mm:ss (Thomas)

- New xid/int comparison functions (Hiroshi)
- Add precision to TIME, TIMESTAMP, and INTERVAL data types (Thomas)
- Modify type coercion logic to attempt binary-compatible functions first (Tom)
- New encode() function installed by default (Marko Kreen)
- Improved to_*() conversion functions (Karel Zak)
- Optimize LIKE/ILIKE when using single-byte encodings (Tatsuo)
- New functions in contrib/pgcrypto: crypt(), hmac(), encrypt(), gen_salt() (Marko Kreen)
- Correct description of translate() function (Bruce)
- Add INTERVAL argument for SET TIME ZONE (Thomas)
- Add INTERVAL YEAR TO MONTH (etc.) syntax (Thomas)
- Optimize length functions when using single-byte encodings (Tatsuo)
- Fix path_inter, path_distance, path_length, dist_ppath to handle closed paths (Curtis Barrett, Tom)
- octet_length(text) now returns non-compressed length (Tatsuo, Bruce)
- Handle "July" full name in date/time literals (Greg Sabino Mullane)
- Some datatype() function calls now evaluated differently
- Add support for Julian and ISO time specifications (Thomas)

E.240.3.10. Internationalization

- National language support in psql, pg_dump, libpq, and server (Peter E)
- Message translations in Chinese (simplified, traditional), Czech, French, German, Hungarian, Russian, Swedish (Peter E, Serguei A. Mokhov, Karel Zak, Weiping He, Zhenbang Wei, Kovacs Zoltan)
- Make trim, ltrim, rtrim, btrim, lpad, rpad, translate multibyte aware (Tatsuo)
- Add LATIN5,6,7,8,9,10 support (Tatsuo)
- Add ISO 8859-5,6,7,8 support (Tatsuo)
- Correct LATIN5 to mean ISO-8859-9, not ISO-8859-5 (Tatsuo)
- Make mic2ascii() non-ASCII aware (Tatsuo)
- Reject invalid multibyte character sequences (Tatsuo)

E.240.3.11. PL/pgSQL

- Now uses portals for SELECT loops, allowing huge result sets (Jan)
- CURSOR and REFCURSOR support (Jan)
- Can now return open cursors (Jan)
- Add ELSEIF (Klaus Reger)
- Improve PL/pgSQL error reporting, including location of error (Tom)
- Allow IS or FOR key words in cursor declaration, for compatibility (Bruce)
- Fix for SELECT ... FOR UPDATE (Tom)

- Fix for PERFORM returning multiple rows (Tom)
- Make PL/pgSQL use the server's type coercion code (Tom)
- Memory leak fix (Jan, Tom)
- Make trailing semicolon optional (Tom)

E.240.3.12. PL/Perl

- New untrusted PL/Perl (Alex Pilosov)
- PL/Perl is now built on some platforms even if libperl is not shared (Peter E)

E.240.3.13. PL/Tcl

- Now reports errorInfo (Vsevolod Lobko)
- Add spi_lastoid function (bob@redivi.com)

E.240.3.14. PL/Python

- ...is new (Andrew Bosma)

E.240.3.15. psql

- \d displays indexes in unique, primary groupings (Christopher Kings-Lynne)
- Allow trailing semicolons in backslash commands (Greg Sabino Mullane)
- Read password from /dev/tty if possible
- Force new password prompt when changing user and database (Tatsuo, Tom)
- Format the correct number of columns for Unicode (Patrice)

E.240.3.16. libpq

- New function PQescapeString() to escape quotes in command strings (Florian Weimer)
- New function PQescapeBytea() escapes binary strings for use as SQL string literals

E.240.3.17. JDBC

- Return OID of INSERT (Ken K)
- Handle more data types (Ken K)
- Handle single quotes and newlines in strings (Ken K)
- Handle NULL variables (Ken K)

- Fix for time zone handling (Barry Lind)
- Improved Druid support
- Allow eight-bit characters with non-multibyte server (Barry Lind)
- Support BIT, BINARY types (Ned Wolpert)
- Reduce memory usage (Michael Stephens, Dave Cramer)
- Update DatabaseMetaData (Peter E)
- Add DatabaseMetaData.getCatalogs() (Peter E)
- Encoding fixes (Anders Bengtsson)
- Get/setCatalog methods (Jason Davies)
- DatabaseMetaData.getColumns() now returns column defaults (Jason Davies)
- DatabaseMetaData.getColumns() performance improvement (Jeroen van Vianen)
- Some JDBC1 and JDBC2 merging (Anders Bengtsson)
- Transaction performance improvements (Barry Lind)
- Array fixes (Greg Zoller)
- Serialize addition
- Fix batch processing (Rene Pijlman)
- ExecSQL method reorganization (Anders Bengtsson)
- GetColumn() fixes (Jeroen van Vianen)
- Fix isWriteable() function (Rene Pijlman)
- Improved passage of JDBC2 conformance tests (Rene Pijlman)
- Add bytea type capability (Barry Lind)
- Add isNullable() (Rene Pijlman)
- JDBC date/time test suite fixes (Liam Stewart)
- Fix for SELECT 'id' AS xxx FROM table (Dave Cramer)
- Fix DatabaseMetaData to show precision properly (Mark Lillywhite)
- New getImported/getExported keys (Jason Davies)
- MD5 password encryption support (Jeremy Wohl)
- Fix to actually use type cache (Ned Wolpert)

E.240.3.18. ODBC

- Remove query size limit (Hiroshi)
- Remove text field size limit (Hiroshi)
- Fix for SQLPrimaryKeys in multibyte mode (Hiroshi)
- Allow ODBC procedure calls (Hiroshi)
- Improve boolean handing (Aidan Mountford)
- Most configuration options now settable via DSN (Hiroshi)

- Multibyte, performance fixes (Hiroshi)
- Allow driver to be used with iODBC or unixODBC (Peter E)
- MD5 password encryption support (Bruce)
- Add more compatibility functions to odbc.sql (Peter E)

E.240.3.19. ECPG

- EXECUTE ... INTO implemented (Christof Petig)
- Multiple row descriptor support (e.g. CARDINALITY) (Christof Petig)
- Fix for GRANT parameters (Lee Kindness)
- Fix INITIALLY DEFERRED bug
- Various bug fixes (Michael, Christof Petig)
- Auto allocation for indicator variable arrays (int *ind_p=NULL)
- Auto allocation for string arrays (char **foo_pp=NULL)
- ECPGfree_auto_mem fixed
- All function names with external linkage are now prefixed by ECPG
- Fixes for arrays of structures (Michael)

E.240.3.20. Misc. Interfaces

- Python fix fetchone() (Gerhard Haring)
- Use UTF, Unicode in Tcl where appropriate (Vsevolod Lobko, Reinhard Max)
- Add Tcl COPY TO/FROM (ljb)
- Prevent output of default index op class in pg_dump (Tom)
- Fix libpgeasy memory leak (Bruce)

E.240.3.21. Build and Install

- Configure, dynamic loader, and shared library fixes (Peter E)
- Fixes in QNX 4 port (Bernd Tegge)
- Fixes in Cygwin and Windows ports (Jason Tishler, Gerhard Haring, Dmitry Yurtaev, Darko Prenosil, Mikhail Terekhov)
- Fix for Windows socket communication failures (Magnus, Mikhail Terekhov)
- Hurd compile fix (Oliver Elphick)
- BeOS fixes (Cyril Velter)
- Remove configure --enable-unicode-conversion, now enabled by multibyte (Tatsuo)
- AIX fixes (Tatsuo, Andreas)
- Fix parallel make (Peter E)

- Install SQL language manual pages into OS-specific directories (Peter E)
- Rename config.h to pg_config.h (Peter E)
- Reorganize installation layout of header files (Peter E)

E.240.3.22. Source Code

- Remove SEP_CHAR (Bruce)
- New GUC hooks (Tom)
- Merge GUC and command line handling (Marko Kreen)
- Remove EXTEND INDEX (Martijn van Oosterhout, Tom)
- New pgjindent utility to indent java code (Bruce)
- Remove define of true/false when compiling under C++ (Leandro Fanzone, Tom)
- pgindent fixes (Bruce, Tom)
- Replace strcasecmp() with strcmp() where appropriate (Peter E)
- Dynahash portability improvements (Tom)
- Add 'volatile' usage in spinlock structures
- Improve signal handling logic (Tom)

E.240.3.23. Contrib

- New contrib/rtree_gist (Oleg Bartunov, Teodor Sigaev)
- New contrib/tsearch full-text indexing (Oleg, Teodor Sigaev)
- Add contrib/dblink for remote database access (Joe Conway)
- contrib/ora2pg Oracle conversion utility (Gilles Darold)
- contrib/xml XML conversion utility (John Gray)
- contrib/fulltextindex fixes (Christopher Kings-Lynne)
- New contrib/fuzzystrmatch with levenshtein and metaphone, soundex merged (Joe Conway)
- Add contrib/intarray boolean queries, binary search, fixes (Oleg Bartunov)
- New pg_upgrade utility (Bruce)
- Add new pg_resetxlog options (Bruce, Tom)

E.241. Release 7.1.3

Release Date: 2001-08-15

E.241.1. Migration to Version 7.1.3

A dump/restore is *not* required for those running 7.1.X.

E.241.2. Changes

```
Remove unused WAL segments of large transactions (Tom)
Multiaction rule fix (Tom)
PL/pgSQL memory allocation fix (Jan)
VACUUM buffer fix (Tom)
Regression test fixes (Tom)
pg_dump fixes for GRANT/REVOKE/comments on views, user-defined types (Tom)
Fix subselects with DISTINCT ON or LIMIT (Tom)
BeOS fix
Disable COPY TO/FROM a view (Tom)
Cygwin build (Jason Tishler)
```

E.242. Release 7.1.2

Release Date: 2001-05-11

This has one fix from 7.1.1.

E.242.1. Migration to Version 7.1.2

A dump/restore is *not* required for those running 7.1.X.

E.242.2. Changes

```
Fix PL/pgSQL SELECTs when returning no rows
Fix for psql backslash core dump
Referential integrity privilege fix
Optimizer fixes
pg_dump cleanups
```

E.243. Release 7.1.1

Release Date: 2001-05-05

This has a variety of fixes from 7.1.

E.243.1. Migration to Version 7.1.1

A dump/restore is *not* required for those running 7.1.

E.243.2. Changes

```
Fix for numeric MODULO operator (Tom)
pg_dump fixes (Philip)
pg_dump can dump 7.0 databases (Philip)
readline 4.2 fixes (Peter E)
JOIN fixes (Tom)
AIX, MSWIN, VAX, N32K fixes (Tom)
Multibytes fixes (Tom)
Unicode fixes (Tatsuo)
Optimizer improvements (Tom)
Fix for whole rows in functions (Tom)
Fix for pg_ctl and option strings with spaces (Peter E)
ODBC fixes (Hiroshi)
EXTRACT can now take string argument (Thomas)
Python fixes (Darcy)
```

E.244. Release 7.1

Release Date: 2001-04-13

This release focuses on removing limitations that have existed in the PostgreSQL code for many years.

Major changes in this release:

Write-ahead Log (WAL)

To maintain database consistency in case of an operating system crash, previous releases of PostgreSQL have forced all data modifications to disk before each transaction commit. With WAL, only one log file must be flushed to disk, greatly improving performance. If you have been using -F in previous releases to disable disk flushes, you might want to consider discontinuing its use.

TOAST

TOAST - Previous releases had a compiled-in row length limit, typically 8k - 32k. This limit made storage of long text fields difficult. With TOAST, long rows of any length can be stored with good performance.

Outer Joins

We now support outer joins. The UNION/NOT IN workaround for outer joins is no longer required. We use the SQL92 outer join syntax.

Function Manager

The previous C function manager did not handle null values properly, nor did it support 64-bit CPU's (Alpha). The new function manager does. You can continue using your old custom functions, but you might want to rewrite them in the future to use the new function manager call interface.

Complex Queries

A large number of complex queries that were unsupported in previous releases now work. Many combinations of views, aggregates, UNION, LIMIT, cursors, subqueries, and inherited tables now work properly. Inherited tables are now accessed by default. Subqueries in FROM are now supported.

E.244.1. Migration to Version 7.1

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release.

E.244.2. Changes

```
Bug Fixes
---------
Many multibyte/Unicode/locale fixes (Tatsuo and others)
More reliable ALTER TABLE RENAME (Tom)
Kerberos V fixes (David Wragg)
Fix for INSERT INTO...SELECT where targetlist has subqueries (Tom)
Prompt username/password on standard error (Bruce)
Large objects inv_read/inv_write fixes (Tom)
Fixes for to_char(), to_date(), to_ascii(), and to_timestamp() (Karel,
   Daniel Baldoni)
Prevent query expressions from leaking memory (Tom)
Allow UPDATE of arrays elements (Tom)
Wake up lock waiters during cancel (Hiroshi)
Fix rare cursor crash when using hash join (Tom)
Fix for DROP TABLE/INDEX in rolled-back transaction (Hiroshi)
Fix psql crash from \l+ if MULTIBYTE enabled (Peter E)
Fix truncation of rule names during CREATE VIEW (Ross Reedstrom)
Fix PL/perl (Alex Kapranoff)
Disallow LOCK on views (Mark Hollomon)
Disallow INSERT/UPDATE/DELETE on views (Mark Hollomon)
Disallow DROP RULE, CREATE INDEX, TRUNCATE on views (Mark Hollomon)
Allow PL/pgSQL accept non-ASCII identifiers (Tatsuo)
Allow views to proper handle GROUP BY, aggregates, DISTINCT (Tom)
Fix rare failure with TRUNCATE command (Tom)
Allow UNION/INTERSECT/EXCEPT to be used with ALL, subqueries, views,
   DISTINCT, ORDER BY, SELECT...INTO (Tom)
Fix parser failures during aborted transactions (Tom)
Allow temporary relations to properly clean up indexes (Bruce)
Fix VACUUM problem with moving rows in same page (Tom)
```

```
Modify pg_dump to better handle user-defined items in template1 (Philip)
Allow LIMIT in VIEW (Tom)
Require cursor FETCH to honor LIMIT (Tom)
Allow PRIMARY/FOREIGN Key definitions on inherited columns (Stephan)
Allow ORDER BY, LIMIT in subqueries (Tom)
Allow UNION in CREATE RULE (Tom)
Make ALTER/DROP TABLE rollback-able (Vadim, Tom)
Store initdb collation in pg_control so collation cannot be changed (Tom)
Fix INSERT...SELECT with rules (Tom)
Fix FOR UPDATE inside views and subselects (Tom)
Fix OVERLAPS operators conform to SQL92 spec regarding NULLs (Tom)
Fix lpad() and rpad() to handle length less than input string (Tom)
Fix use of NOTIFY in some rules (Tom)
Overhaul btree code (Tom)
Fix NOT NULL use in Pl/pgSQL variables (Tom)
Overhaul GIST code (Oleg)
Fix CLUSTER to preserve constraints and column default (Tom)
Improved deadlock detection handling (Tom)
Allow multiple SERIAL columns in a table (Tom)
Prevent occasional index corruption (Vadim)

Enhancements
------------
Add OUTER JOINs (Tom)
Function manager overhaul (Tom)
Allow ALTER TABLE RENAME on indexes (Tom)
Improve CLUSTER (Tom)
Improve ps status display for more platforms (Peter E, Marc)
Improve CREATE FUNCTION failure message (Ross)
JDBC improvements (Peter, Travis Bauer, Christopher Cain, William Webber,
   Gunnar)
Grand Unified Configuration scheme/GUC.  Many options can now be set in
   data/postgresql.conf, postmaster/postgres flags, or SET commands (Peter E)
Improved handling of file descriptor cache (Tom)
New warning code about auto-created table alias entries (Bruce)
Overhaul initdb process (Tom, Peter E)
Overhaul of inherited tables; inherited tables now accessed by default;
  new ONLY key word prevents it (Chris Bitmead, Tom)
ODBC cleanups/improvements (Nick Gorham, Stephan Szabo, Zoltan Kovacs,
   Michael Fork)
Allow renaming of temp tables (Tom)
Overhaul memory manager contexts (Tom)
pg_dumpall uses CREATE USER or CREATE GROUP rather using COPY (Peter E)
Overhaul pg_dump (Philip Warner)
Allow pg_hba.conf secondary password file to specify only username (Peter E)
Allow TEMPORARY or TEMP key word when creating temporary tables (Bruce)
New memory leak checker (Karel)
New SET SESSION CHARACTERISTICS (Thomas)
Allow nested block comments (Thomas)
Add WITHOUT TIME ZONE type qualifier (Thomas)
New ALTER TABLE ADD CONSTRAINT (Stephan)
Use NUMERIC accumulators for INTEGER aggregates (Tom)
Overhaul aggregate code (Tom)
New VARIANCE and STDDEV() aggregates
Improve dependency ordering of pg_dump (Philip)
New pg_restore command (Philip)
New pg_dump tar output option (Philip)
```

```
New pg_dump of large objects  (Philip)
New ESCAPE option to LIKE (Thomas)
New case-insensitive LIKE - ILIKE (Thomas)
Allow functional indexes to use binary-compatible type (Tom)
Allow SQL functions to be used in more contexts (Tom)
New pg_config utility (Peter E)
New PL/pgSQL EXECUTE command which allows dynamic SQL and utility statements
   (Jan)
New PL/pgSQL GET DIAGNOSTICS statement for SPI value access (Jan)
New quote_identifiers() and quote_literal() functions (Jan)
New ALTER TABLE table OWNER TO user command (Mark Hollomon)
Allow subselects in FROM, i.e. FROM (SELECT ...) [AS] alias (Tom)
Update PyGreSQL to version 3.1 (D'Arcy)
Store tables as files named by OID (Vadim)
New SQL function setval(seq,val,bool) for use in pg_dump (Philip)
Require DROP VIEW to remove views, no DROP TABLE (Mark)
Allow DROP VIEW view1, view2 (Mark)
Allow multiple objects in DROP INDEX, DROP RULE, and DROP TYPE (Tom)
Allow automatic conversion to/from Unicode (Tatsuo, Eiji)
New /contrib/pgcrypto hashing functions (Marko Kreen)
New pg_dumpall --globals-only option (Peter E)
New CHECKPOINT command for WAL which creates new WAL log file (Vadim)
New AT TIME ZONE syntax (Thomas)
Allow location of Unix domain socket to be configurable (David J. MacKenzie)
Allow postmaster to listen on a specific IP address (David J. MacKenzie)
Allow socket path name to be specified in hostname by using leading slash
   (David J. MacKenzie)
Allow CREATE DATABASE to specify template database (Tom)
New utility to convert MySQL schema dumps to SQL92 and PostgreSQL (Thomas)
New /contrib/rserv replication toolkit (Vadim)
New file format for COPY BINARY (Tom)
New /contrib/oid2name to map numeric files to table names (B Palmer)
New "idle in transaction" ps status message (Marc)
Update to pgaccess 0.98.7 (Constantin Teodorescu)
pg_ctl now defaults to -w (wait) on shutdown, new -l (log) option
Add rudimentary dependency checking to pg_dump (Philip)

Types
-----
Fix INET/CIDR type ordering and add new functions (Tom)
Make OID behave as an unsigned type (Tom)
Allow BIGINT as synonym for INT8 (Peter E)
New int2 and int8 comparison operators (Tom)
New BIT and BIT VARYING types (Adriaan Joubert, Tom, Peter E)
CHAR() no longer faster than VARCHAR() because of TOAST (Tom)
New GIST seg/cube examples (Gene Selkov)
Improved round(numeric) handling (Tom)
Fix CIDR output formatting (Tom)
New CIDR abbrev() function (Tom)

Performance
-----------
Write-Ahead Log (WAL) to provide crash recovery with less performance
   overhead (Vadim)
ANALYZE stage of VACUUM no longer exclusively locks table (Bruce)
Reduced file seeks (Denis Perchine)
Improve BTREE code for duplicate keys (Tom)
```

```
Store all large objects in a single table (Denis Perchine, Tom)
Improve memory allocation performance (Karel, Tom)

Source Code
-----------
New function manager call conventions (Tom)
SGI portability fixes (David Kaelbling)
New configure --enable-syslog option (Peter E)
New BSDI README (Bruce)
configure script moved to top level, not /src (Peter E)
Makefile/configuration/compilation overhaul (Peter E)
New configure --with-python option (Peter E)
Solaris cleanups (Peter E)
Overhaul /contrib Makefiles (Karel)
New OpenSSL configuration option (Magnus, Peter E)
AIX fixes (Andreas)
QNX fixes (Maurizio)
New heap_open(), heap_openr() API (Tom)
Remove colon and semi-colon operators (Thomas)
New pg_class.relkind value for views (Mark Hollomon)
Rename ichar() to chr() (Karel)
New documentation for btrim(), ascii(), chr(), repeat() (Karel)
Fixes for NT/Cygwin (Pete Forman)
AIX port fixes (Andreas)
New BeOS port (David Reid, Cyril Velter)
Add proofreader's changes to docs (Addison-Wesley, Bruce)
New Alpha spinlock code (Adriaan Joubert, Compaq)
UnixWare port overhaul (Peter E)
New Darwin/Mac OS X port (Peter Bierman, Bruce Hartzler)
New FreeBSD Alpha port (Alfred)
Overhaul shared memory segments (Tom)
Add IBM S/390 support (Neale Ferguson)
Moved macmanuf to /contrib (Larry Rosenman)
Syslog improvements (Larry Rosenman)
New template0 database that contains no user additions (Tom)
New /contrib/cube and /contrib/seg GIST sample code (Gene Selkov)
Allow NetBSD's libedit instead of readline (Peter)
Improved assembly language source code format (Bruce)
New contrib/pg_logger
New --template option to createdb
New contrib/pg_control utility (Oliver)
New FreeBSD tools ipc_check, start-scripts/freebsd
```

E.245. Release 7.0.3

Release Date: 2000-11-11

This has a variety of fixes from 7.0.2.

E.245.1. Migration to Version 7.0.3

A dump/restore is *not* required for those running 7.0.*.

E.245.2. Changes

```
Jdbc fixes (Peter)
Large object fix (Tom)
Fix lean in COPY WITH OIDS leak (Tom)
Fix backwards-index-scan (Tom)
Fix SELECT ... FOR UPDATE so it checks for duplicate keys (Hiroshi)
Add --enable-syslog to configure (Marc)
Fix abort transaction at backend exit in rare cases (Tom)
Fix for psql \l+ when multibyte enabled (Tatsuo)
Allow PL/pgSQL to accept non ascii identifiers (Tatsuo)
Make vacuum always flush buffers (Tom)
Fix to allow cancel while waiting for a lock (Hiroshi)
Fix for memory allocation problem in user authentication code (Tom)
Remove bogus use of int4out() (Tom)
Fixes for multiple subqueries in COALESCE or BETWEEN (Tom)
Fix for failure of triggers on heap open in certain cases (Jeroen van
   Vianen)
Fix for erroneous selectivity of not-equals (Tom)
Fix for erroneous use of strcmp() (Tom)
Fix for bug where storage manager accesses items beyond end of file
   (Tom)
Fix to include kernel errno message in all smgr elog messages (Tom)
Fix for '.' not in PATH at build time (SL Baur)
Fix for out-of-file-descriptors error (Tom)
Fix to make pg_dump dump 'iscachable' flag for functions (Tom)
Fix for subselect in targetlist of Append node (Tom)
Fix for mergejoin plans (Tom)
Fix TRUNCATE failure on relations with indexes (Tom)
Avoid database-wide restart on write error (Hiroshi)
Fix nodeMaterial to honor chgParam by recomputing its output (Tom)
Fix VACUUM problem with moving chain of update row versions when source
   and destination of a row version lie on the same page (Tom)
Fix user.c CommandCounterIncrement (Tom)
Fix for AM/PM boundary problem in to_char() (Karel Zak)
Fix TIME aggregate handling (Tom)
Fix to_char() to avoid coredump on NULL input (Tom)
Buffer fix (Tom)
Fix for inserting/copying longer multibyte strings into char() data
   types (Tatsuo)
Fix for crash of backend, on abort (Tom)
```

E.246. Release 7.0.2

Release Date: 2000-06-05

This is a repackaging of 7.0.1 with added documentation.

E.246.1. Migration to Version 7.0.2

A dump/restore is *not* required for those running 7.*.

E.246.2. Changes

```
Added documentation to tarball.
```

E.247. Release 7.0.1

Release Date: 2000-06-01

This is a cleanup release for 7.0.

E.247.1. Migration to Version 7.0.1

A dump/restore is *not* required for those running 7.0.

E.247.2. Changes

```
Fix many CLUSTER failures (Tom)
Allow ALTER TABLE RENAME works on indexes (Tom)
Fix plpgsql to handle datetime->timestamp and timespan->interval (Bruce)
New configure --with-setproctitle switch to use setproctitle() (Marc, Bruce)
Fix the off by one errors in ResultSet from 6.5.3, and more.
jdbc ResultSet fixes (Joseph Shraibman)
optimizer tunings (Tom)
Fix create user for pgaccess
Fix for UNLISTEN failure
IRIX fixes (David Kaelbling)
QNX fixes (Andreas Kardos)
Reduce COPY IN lock level (Tom)
Change libpqeasy to use PQconnectdb() style parameters (Bruce)
Fix pg_dump to handle OID indexes (Tom)
Fix small memory leak (Tom)
```

```
Solaris fix for createdb/dropdb (Tatsuo)
Fix for non-blocking connections (Alfred Perlstein)
Fix improper recovery after RENAME TABLE failures (Tom)
Copy pg_ident.conf.sample into /lib directory in install (Bruce)
Add SJIS UDC (NEC selection IBM kanji) support (Eiji Tokuya)
Fix too long syslog message (Tatsuo)
Fix problem with quoted indexes that are too long (Tom)
JDBC ResultSet.getTimestamp() fix (Gregory Krasnow & Floyd Marinescu)
ecpg changes (Michael)
```

E.248. Release 7.0

Release Date: 2000-05-08

This release contains improvements in many areas, demonstrating the continued growth of PostgreSQL. There are more improvements and fixes in 7.0 than in any previous release. The developers have confidence that this is the best release yet; we do our best to put out only solid releases, and this one is no exception.

Major changes in this release:

Foreign Keys

Foreign keys are now implemented, with the exception of PARTIAL MATCH foreign keys. Many users have been asking for this feature, and we are pleased to offer it.

Optimizer Overhaul

Continuing on work started a year ago, the optimizer has been improved, allowing better query plan selection and faster performance with less memory usage.

Updated psql

psql, our interactive terminal monitor, has been updated with a variety of new features. See the psql manual page for details.

Join Syntax

SQL92 join syntax is now supported, though only as `INNER JOIN` for this release. `JOIN`, `NATURAL JOIN`, `JOIN`/`USING`, and `JOIN`/`ON` are available, as are column correlation names.

E.248.1. Migration to Version 7.0

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release of PostgreSQL. For those upgrading from 6.5.*, you can instead use pg_upgrade to upgrade to this release; however, a full dump/reload installation is always the most robust method for upgrades.

Interface and compatibility issues to consider for the new release include:

- The date/time types `datetime` and `timespan` have been superseded by the SQL92-defined types `timestamp` and `interval`. Although there has been some effort to ease the transition by allowing

PostgreSQL to recognize the deprecated type names and translate them to the new type names, this mechanism cannot be completely transparent to your existing application.

- The optimizer has been substantially improved in the area of query cost estimation. In some cases, this will result in decreased query times as the optimizer makes a better choice for the preferred plan. However, in a small number of cases, usually involving pathological distributions of data, your query times might go up. If you are dealing with large amounts of data, you might want to check your queries to verify performance.
- The JDBC and ODBC interfaces have been upgraded and extended.
- The string function `CHAR_LENGTH` is now a native function. Previous versions translated this into a call to `LENGTH`, which could result in ambiguity with other types implementing `LENGTH` such as the geometric types.

E.248.2. Changes

```
Bug Fixes
---------
Prevent function calls exceeding maximum number of arguments (Tom)
Improve CASE construct (Tom)
Fix SELECT coalesce(f1,0) FROM int4_tbl GROUP BY f1 (Tom)
Fix SELECT sentence.words[0] FROM sentence GROUP BY sentence.words[0] (Tom)
Fix GROUP BY scan bug (Tom)
Improvements in SQL grammar processing (Tom)
Fix for views involved in INSERT ... SELECT ... (Tom)
Fix for SELECT a/2, a/2 FROM test_missing_target GROUP BY a/2 (Tom)
Fix for subselects in INSERT ... SELECT (Tom)
Prevent INSERT ... SELECT ... ORDER BY (Tom)
Fixes for relations greater than 2GB, including vacuum
Improve propagating system table changes to other backends (Tom)
Improve propagating user table changes to other backends (Tom)
Fix handling of temp tables in complex situations (Bruce, Tom)
Allow table locking at table open, improving concurrent reliability (Tom)
Properly quote sequence names in pg_dump (Ross J. Reedstrom)
Prevent DROP DATABASE while others accessing
Prevent any rows from being returned by GROUP BY if no rows processed (Tom)
Fix SELECT COUNT(1) FROM table WHERE ...' if no rows matching WHERE (Tom)
Fix pg_upgrade so it works for MVCC (Tom)
Fix for SELECT ... WHERE x IN (SELECT ... HAVING SUM(x) > 1) (Tom)
Fix for "f1 datetime DEFAULT 'now'"  (Tom)
Fix problems with CURRENT_DATE used in DEFAULT (Tom)
Allow comment-only lines, and ;;; lines too. (Tom)
Improve recovery after failed disk writes, disk full (Hiroshi)
Fix cases where table is mentioned in FROM but not joined (Tom)
Allow HAVING clause without aggregate functions (Tom)
Fix for "--" comment and no trailing newline, as seen in perl interface
Improve pg_dump failure error reports (Bruce)
Allow sorts and hashes to exceed 2GB file sizes (Tom)
Fix for pg_dump dumping of inherited rules (Tom)
Fix for NULL handling comparisons (Tom)
Fix inconsistent state caused by failed CREATE/DROP commands (Hiroshi)
Fix for dbname with dash
Prevent DROP INDEX from interfering with other backends (Tom)
Fix file descriptor leak in verify_password()
Fix for "Unable to identify an operator =$" problem
```

```
Fix ODBC so no segfault if CommLog and Debug enabled (Dirk Niggemann)
Fix for recursive exit call (Massimo)
Fix for extra-long timezones (Jeroen van Vianen)
Make pg_dump preserve primary key information (Peter E)
Prevent databases with single quotes (Peter E)
Prevent DROP DATABASE inside  transaction (Peter E)
ecpg memory leak fixes (Stephen Birch)
Fix for SELECT null::text, SELECT int4fac(null) and SELECT 2 + (null) (Tom)
Y2K timestamp fix (Massimo)
Fix for VACUUM 'HEAP_MOVED_IN was not expected' errors (Tom)
Fix for views with tables/columns containing spaces  (Tom)
Prevent privileges on indexes (Peter E)
Fix for spinlock stuck problem when error is generated (Hiroshi)
Fix ipcclean on Linux
Fix handling of NULL constraint conditions (Tom)
Fix memory leak in odbc driver (Nick Gorham)
Fix for privilege check on UNION tables (Tom)
Fix to allow SELECT 'a' LIKE 'a' (Tom)
Fix for SELECT 1 + NULL (Tom)
Fixes to CHAR
Fix log() on numeric type (Tom)
Deprecate ':' and ';' operators
Allow vacuum of temporary tables
Disallow inherited columns with the same name as new columns
Recover or force failure when disk space is exhausted (Hiroshi)
Fix INSERT INTO ... SELECT with AS columns matching result columns
Fix INSERT ... SELECT ... GROUP BY groups by target columns not source columns (Tom)
Fix CREATE TABLE test (a char(5) DEFAULT text '', b int4) with INSERT (Tom)
Fix UNION with LIMIT
Fix CREATE TABLE x AS SELECT 1 UNION SELECT 2
Fix CREATE TABLE test(col char(2) DEFAULT user)
Fix mismatched types in CREATE TABLE ... DEFAULT
Fix SELECT * FROM pg_class where oid in (0,-1)
Fix SELECT COUNT('asdf') FROM pg_class WHERE oid=12
Prevent user who can create databases can modifying pg_database table (Peter E)
Fix btree to give a useful elog when key > 1/2 (page - overhead) (Tom)
Fix INSERT of 0.0 into DECIMAL(4,4) field (Tom)

Enhancements
------------
New CLI interface include file sqlcli.h, based on SQL3/SQL98
Remove all limits on query length, row length limit still exists (Tom)
Update jdbc protocol to 2.0 (Jens Glaser <jens@jens.de>)
Add TRUNCATE command to quickly truncate relation (Mike Mascari)
Fix to give super user and createdb user proper update catalog rights (Peter E)
Allow ecpg bool variables to have NULL values (Christof)
Issue ecpg error if NULL value for variable with no NULL indicator (Christof)
Allow ^C to cancel COPY command (Massimo)
Add SET FSYNC and SHOW PG_OPTIONS commands(Massimo)
Function name overloading for dynamically-loaded C functions (Frankpitt)
Add CmdTuples() to libpq++(Vince)
New CREATE CONSTRAINT TRIGGER and SET CONSTRAINTS commands(Jan)
Allow CREATE FUNCTION/WITH clause to be used for all language types
configure --enable-debug adds -g (Peter E)
configure --disable-debug removes -g (Peter E)
Allow more complex default expressions (Tom)
First real FOREIGN KEY constraint trigger functionality (Jan)
```

Add FOREIGN KEY ... MATCH FULL ... ON DELETE CASCADE (Jan)
Add FOREIGN KEY ... MATCH <unspecified> referential actions (Don Baccus)
Allow WHERE restriction on ctid (physical heap location) (Hiroshi)
Move pginterface from contrib to interface directory, rename to pgeasy (Bruce)
Change pgeasy connectdb() parameter ordering (Bruce)
Require SELECT DISTINCT target list to have all ORDER BY columns (Tom)
Add Oracle's COMMENT ON command (Mike Mascari <mascarim@yahoo.com>)
libpq's PQsetNoticeProcessor function now returns previous hook(Peter E)
Prevent PQsetNoticeProcessor from being set to NULL (Peter E)
Make USING in COPY optional (Bruce)
Allow subselects in the target list (Tom)
Allow subselects on the left side of comparison operators (Tom)
New parallel regression test (Jan)
Change backend-side COPY to write files with permissions 644 not 666 (Tom)
Force permissions on PGDATA directory to be secure, even if it exists (Tom)
Added psql LASTOID variable to return last inserted oid (Peter E)
Allow concurrent vacuum and remove pg_vlock vacuum lock file (Tom)
Add privilege check for vacuum (Peter E)
New libpq functions to allow asynchronous connections: PQconnectStart(),
  PQconnectPoll(), PQresetStart(), PQresetPoll(), PQsetenvStart(),
  PQsetenvPoll(), PQsetenvAbort (Ewan Mellor)
New libpq PQsetenv() function (Ewan Mellor)
create/alter user extension (Peter E)
New postmaster.pid and postmaster.opts under $PGDATA (Tatsuo)
New scripts for create/drop user/db (Peter E)
Major psql overhaul (Peter E)
Add const to libpq interface (Peter E)
New libpq function PQoidValue (Peter E)
Show specific non-aggregate causing problem with GROUP BY (Tom)
Make changes to pg_shadow recreate pg_pwd file (Peter E)
Add aggregate(DISTINCT ...) (Tom)
Allow flag to control COPY input/output of NULLs (Peter E)
Make postgres user have a password by default (Peter E)
Add CREATE/ALTER/DROP GROUP (Peter E)
All administration scripts now support --long options (Peter E, Karel)
Vacuumdb script now supports --all option (Peter E)
ecpg new portable FETCH syntax
Add ecpg EXEC SQL IFDEF, EXEC SQL IFNDEF, EXEC SQL ELSE, EXEC SQL ELIF
       and EXEC SQL ENDIF directives
Add pg_ctl script to control backend start-up (Tatsuo)
Add postmaster.opts.default file to store start-up flags (Tatsuo)
Allow --with-mb=SQL_ASCII
Increase maximum number of index keys to 16 (Bruce)
Increase maximum number of function arguments to 16 (Bruce)
Allow configuration of maximum number of index keys and arguments (Bruce)
Allow unprivileged users to change their passwords (Peter E)
Password authentication enabled; required for new users (Peter E)
Disallow dropping a user who owns a database (Peter E)
Change initdb option --with-mb to --enable-multibyte
Add option for initdb to prompts for superuser password (Peter E)
Allow complex type casts like col::numeric(9,2) and col::int2::float8 (Tom)
Updated user interfaces on initdb, initlocation, pg_dump, ipcclean (Peter E)
New pg_char_to_encoding() and pg_encoding_to_char() functions (Tatsuo)
libpq non-blocking mode (Alfred Perlstein)
Improve conversion of types in casts that don't specify a length
New plperl internal programming language (Mark Hollomon)
Allow COPY IN to read file that do not end with a newline (Tom)

```
Indicate when long identifiers are truncated (Tom)
Allow aggregates to use type equivalency (Peter E)
Add Oracle's to_char(), to_date(), to_datetime(), to_timestamp(), to_number()
       conversion functions (Karel Zak <zakkr@zf.jcu.cz>)
Add SELECT DISTINCT ON (expr [, expr ...]) targetlist ... (Tom)
Check to be sure ORDER BY is compatible with the DISTINCT operation (Tom)
Add NUMERIC and int8 types to ODBC
Improve EXPLAIN results for Append, Group, Agg, Unique (Tom)
Add ALTER TABLE ... ADD FOREIGN KEY (Stephan Szabo)
Allow SELECT .. FOR UPDATE in PL/pgSQL (Hiroshi)
Enable backward sequential scan even after reaching EOF (Hiroshi)
Add btree indexing of boolean values, >= and <= (Don Baccus)
Print current line number when COPY FROM fails (Massimo)
Recognize POSIX time zone e.g. "PST+8" and "GMT-8" (Thomas)
Add DEC as synonym for DECIMAL (Thomas)
Add SESSION_USER as SQL92 key word, same as CURRENT_USER (Thomas)
Implement SQL92 column aliases (aka correlation names) (Thomas)
Implement SQL92 join syntax (Thomas)
Make INTERVAL reserved word allowed as a column identifier (Thomas)
Implement REINDEX command (Hiroshi)
Accept ALL in aggregate function SUM(ALL col) (Tom)
Prevent GROUP BY from using column aliases (Tom)
New psql \encoding option (Tatsuo)
Allow PQrequestCancel() to terminate when in waiting-for-lock state (Hiroshi)
Allow negation of a negative number in all cases
Add ecpg descriptors (Christof, Michael)
Allow CREATE VIEW v AS SELECT f1::char(8) FROM tbl
Allow casts with length, like foo::char(8)
New libpq functions PQsetClientEncoding(), PQclientEncoding() (Tatsuo)
Add support for SJIS user defined characters (Tatsuo)
Larger views/rules supported
Make libpq's PQconndefaults() thread-safe (Tom)
Disable // as comment to be ANSI conforming, should use -- (Tom)
Allow column aliases on views CREATE VIEW name (collist)
Fixes for views with subqueries (Tom)
Allow UPDATE table SET fld = (SELECT ...) (Tom)
SET command options no longer require quotes
Update pgaccess to 0.98.6
New SET SEED command
New pg_options.sample file
New SET FSYNC command (Massimo)
Allow pg_descriptions when creating tables
Allow pg_descriptions when creating types, columns, and functions
Allow psql \copy to allow delimiters (Peter E)
Allow psql to print nulls as distinct from "" [null] (Peter E)

Types
-----
Many array fixes (Tom)
Allow bare column names to be subscripted as arrays (Tom)
Improve type casting of int and float constants (Tom)
Cleanups for int8 inputs, range checking, and type conversion (Tom)
Fix for SELECT timespan('21:11:26'::time) (Tom)
netmask('x.x.x.x/0') is 255.255.255.255 instead of 0.0.0.0 (Oleg Sharoiko)
Add btree index on NUMERIC (Jan)
Perl fix for large objects containing NUL characters (Douglas Thomson)
ODBC fix for large objects (free)
```

```
Fix indexing of cidr data type
Fix for Ethernet MAC addresses (macaddr type) comparisons
Fix for date/time types when overflows happened in computations (Tom)
Allow array on int8 (Peter E)
Fix for rounding/overflow of NUMERIC type, like NUMERIC(4,4) (Tom)
Allow NUMERIC arrays
Fix bugs in NUMERIC ceil() and floor() functions (Tom)
Make char_length()/octet_length including trailing blanks (Tom)
Made abstime/reltime use int4 instead of time_t (Peter E)
New lztext data type for compressed text fields
Revise code to handle coercion of int and float constants (Tom)
Start at new code to implement a BIT and BIT VARYING type (Adriaan Joubert)
NUMERIC now accepts scientific notation (Tom)
NUMERIC to int4 rounds (Tom)
Convert float4/8 to NUMERIC properly (Tom)
Allow type conversion with NUMERIC (Thomas)
Make ISO date style (2000-02-16 09:33) the default (Thomas)
Add NATIONAL CHAR [ VARYING ] (Thomas)
Allow NUMERIC round and trunc to accept negative scales (Tom)
New TIME WITH TIME ZONE type (Thomas)
Add MAX()/MIN() on time type (Thomas)
Add abs(), mod(), fac() for int8 (Thomas)
Rename functions to round(), sqrt(), cbrt(), pow() for float8 (Thomas)
Add transcendental math functions (e.g. sin(), acos()) for float8 (Thomas)
Add exp() and ln() for NUMERIC type
Rename NUMERIC power() to pow() (Thomas)
Improved TRANSLATE() function (Edwin Ramirez, Tom)
Allow X=-Y operators  (Tom)
Allow SELECT float8(COUNT(*))/(SELECT COUNT(*) FROM t) FROM t GROUP BY f1; (Tom)
Allow LOCALE to use indexes in regular expression searches (Tom)
Allow creation of functional indexes to use default types

Performance
-----------
Prevent exponential space consumption with many AND's and OR's (Tom)
Collect attribute selectivity values for system columns (Tom)
Reduce memory usage of aggregates (Tom)
Fix for LIKE optimization to use indexes with multibyte encodings (Tom)
Fix r-tree index optimizer selectivity (Thomas)
Improve optimizer selectivity computations and functions (Tom)
Optimize btree searching for cases where many equal keys exist (Tom)
Enable fast LIKE index processing only if index present (Tom)
Re-use free space on index pages with duplicates (Tom)
Improve hash join processing (Tom)
Prevent descending sort if result is already sorted(Hiroshi)
Allow commuting of index scan query qualifications (Tom)
Prefer index scans in cases where ORDER BY/GROUP BY is required (Tom)
Allocate large memory requests in fix-sized chunks for performance (Tom)
Fix vacuum's performance by reducing memory allocation requests (Tom)
Implement constant-expression simplification (Bernard Frankpitt, Tom)
Use secondary columns to be used to determine start of index scan (Hiroshi)
Prevent quadruple use of disk space when doing internal sorting (Tom)
Faster sorting by calling fewer functions (Tom)
Create system indexes to match all system caches (Bruce, Hiroshi)
Make system caches use system indexes (Bruce)
Make all system indexes unique (Bruce)
Improve pg_statistics management for VACUUM speed improvement (Tom)
```

```
Flush backend cache less frequently (Tom, Hiroshi)
COPY now reuses previous memory allocation, improving performance (Tom)
Improve optimization cost estimation (Tom)
Improve optimizer estimate of range queries x > lowbound AND x < highbound (Tom)
Use DNF instead of CNF where appropriate (Tom, Taral)
Further cleanup for OR-of-AND WHERE-clauses (Tom)
Make use of index in OR clauses (x = 1 AND y = 2) OR (x = 2 AND y = 4) (Tom)
Smarter optimizer computations for random index page access (Tom)
New SET variable to control optimizer costs (Tom)
Optimizer queries based on LIMIT, OFFSET, and EXISTS qualifications (Tom)
Reduce optimizer internal housekeeping of join paths for speedup (Tom)
Major subquery speedup (Tom)
Fewer fsync writes when fsync is not disabled (Tom)
Improved LIKE optimizer estimates (Tom)
Prevent fsync in SELECT-only queries (Vadim)
Make index creation use psort code, because it is now faster (Tom)
Allow creation of sort temp tables > 1 Gig

Source Tree Changes
-------------------
Fix for linux PPC compile
New generic expression-tree-walker subroutine (Tom)
Change form() to varargform() to prevent portability problems
Improved range checking for large integers on Alphas
Clean up #include in /include directory (Bruce)
Add scripts for checking includes (Bruce)
Remove un-needed #include's from *.c files (Bruce)
Change #include's to use <> and "" as appropriate (Bruce)
Enable Windows compilation of libpq
Alpha spinlock fix from Uncle George <gatgul@voicenet.com>
Overhaul of optimizer data structures (Tom)
Fix to cygipc library (Yutaka Tanida)
Allow pgsql to work on newer Cygwin snapshots (Dan)
New catalog version number (Tom)
Add Linux ARM
Rename heap_replace to heap_update
Update for QNX (Dr. Andreas Kardos)
New platform-specific regression handling (Tom)
Rename oid8 -> oidvector and int28 -> int2vector (Bruce)
Included all yacc and lex files into the distribution (Peter E.)
Remove lextest, no longer needed (Peter E)
Fix for libpq and psql on Windows (Magnus)
Internally change datetime and timespan into timestamp and interval (Thomas)
Fix for plpgsql on BSD/OS
Add SQL_ASCII test case to the regression test (Tatsuo)
configure --with-mb now deprecated (Tatsuo)
NT fixes
NetBSD fixes (Johnny C. Lam <lamj@stat.cmu.edu>)
Fixes for Alpha compiles
New multibyte encodings
```

E.249. Release 6.5.3

Release Date: 1999-10-13

This is basically a cleanup release for 6.5.2. We have added a new PgAccess that was missing in 6.5.2, and installed an NT-specific fix.

E.249.1. Migration to Version 6.5.3

A dump/restore is *not* required for those running 6.5.*.

E.249.2. Changes

```
Updated version of pgaccess 0.98
NT-specific patch
Fix dumping rules on inherited tables
```

E.250. Release 6.5.2

Release Date: 1999-09-15

This is basically a cleanup release for 6.5.1. We have fixed a variety of problems reported by 6.5.1 users.

E.250.1. Migration to Version 6.5.2

A dump/restore is *not* required for those running 6.5.*.

E.250.2. Changes

```
subselect+CASE fixes(Tom)
Add SHLIB_LINK setting for solaris_i386 and solaris_sparc ports(Daren Sefcik)
Fixes for CASE in WHERE join clauses(Tom)
Fix BTScan abort(Tom)
Repair the check for redundant UNIQUE and PRIMARY KEY indexes(Thomas)
Improve it so that it checks for multicolumn constraints(Thomas)
Fix for Windows making problem with MB enabled(Hiroki Kataoka)
Allow BSD yacc and bison to compile pl code(Bruce)
Fix SET NAMES working
int8 fixes(Thomas)
Fix vacuum's memory consumption(Hiroshi,Tatsuo)
```

```
Reduce the total memory consumption of vacuum(Tom)
Fix for timestamp(datetime)
Rule deparsing bugfixes(Tom)
Fix quoting problems in mkMakefile.tcldefs.sh.in and mkMakefile.tkdefs.sh.in(Tom)
This is to re-use space on index pages freed by vacuum(Vadim)
document -x for pg_dump(Bruce)
Fix for unary operators in rule deparser(Tom)
Comment out FileUnlink of excess segments during mdtruncate()(Tom)
IRIX linking fix from Yu Cao >yucao@falcon.kla-tencor.com<
Repair logic error in LIKE: should not return LIKE_ABORT
  when reach end of pattern before end of text(Tom)
Repair incorrect cleanup of heap memory allocation during transaction abort(Tom)
Updated version of pgaccess 0.98
```

E.251. Release 6.5.1

Release Date: 1999-07-15

This is basically a cleanup release for 6.5. We have fixed a variety of problems reported by 6.5 users.

E.251.1. Migration to Version 6.5.1

A dump/restore is *not* required for those running 6.5.

E.251.2. Changes

```
Add NT README file
Portability fixes for linux_ppc, IRIX, linux_alpha, OpenBSD, alpha
Remove QUERY_LIMIT, use SELECT...LIMIT
Fix for EXPLAIN on inheritance(Tom)
Patch to allow vacuum on multisegment tables(Hiroshi)
R-Tree optimizer selectivity fix(Tom)
ACL file descriptor leak fix(Atsushi Ogawa)
New expression subtree code(Tom)
Avoid disk writes for read-only transactions(Vadim)
Fix for removal of temp tables if last transaction was aborted(Bruce)
Fix to prevent too large row from being created(Bruce)
plpgsql fixes
Allow port numbers 32k - 64k(Bruce)
Add ^ precedence(Bruce)
Rename sort files called pg_temp to pg_sorttemp(Bruce)
Fix for microseconds in time values(Tom)
Tutorial source cleanup
New linux_m68k port
Fix for sorting of NULL's in some cases(Tom)
Shared library dependencies fixed (Tom)
Fixed glitches affecting GROUP BY in subselects(Tom)
```

```
Fix some compiler warnings (Tomoaki Nishiyama)
Add Win1250 (Czech) support (Pavel Behal)
```

E.252. Release 6.5

Release Date: 1999-06-09

This release marks a major step in the development team's mastery of the source code we inherited from Berkeley. You will see we are now easily adding major features, thanks to the increasing size and experience of our world-wide development team.

Here is a brief summary of the more notable changes:

Multiversion concurrency control(MVCC)

This removes our old table-level locking, and replaces it with a locking system that is superior to most commercial database systems. In a traditional system, each row that is modified is locked until committed, preventing reads by other users. MVCC uses the natural multiversion nature of PostgreSQL to allow readers to continue reading consistent data during writer activity. Writers continue to use the compact pg_log transaction system. This is all performed without having to allocate a lock for every row like traditional database systems. So, basically, we no longer are restricted by simple table-level locking; we have something better than row-level locking.

Hot backups from pg_dump

pg_dump takes advantage of the new MVCC features to give a consistent database dump/backup while the database stays online and available for queries.

Numeric data type

We now have a true numeric data type, with user-specified precision.

Temporary tables

Temporary tables are guaranteed to have unique names within a database session, and are destroyed on session exit.

New SQL features

We now have CASE, INTERSECT, and EXCEPT statement support. We have new LIMIT/OFFSET, SET TRANSACTION ISOLATION LEVEL, SELECT ... FOR UPDATE, and an improved LOCK TABLE command.

Speedups

We continue to speed up PostgreSQL, thanks to the variety of talents within our team. We have sped up memory allocation, optimization, table joins, and row transfer routines.

Ports

We continue to expand our port list, this time including Windows NT/ix86 and NetBSD/arm32.

Interfaces

Most interfaces have new versions, and existing functionality has been improved.

Documentation

New and updated material is present throughout the documentation. New FAQs have been contributed for SGI and AIX platforms. The *Tutorial* has introductory information on SQL from Stefan Simkovics. For the *User's Guide*, there are reference pages covering the postmaster and more utility programs, and a new appendix contains details on date/time behavior. The *Administrator's Guide* has a new chapter on troubleshooting from Tom Lane. And the *Programmer's Guide* has a description of query processing, also from Stefan, and details on obtaining the PostgreSQL source tree via anonymous CVS and CVSup.

E.252.1. Migration to Version 6.5

A dump/restore using pg_dump is required for those wishing to migrate data from any previous release of PostgreSQL. pg_upgrade can *not* be used to upgrade to this release because the on-disk structure of the tables has changed compared to previous releases.

The new Multiversion Concurrency Control (MVCC) features can give somewhat different behaviors in multiuser environments. *Read and understand the following section to ensure that your existing applications will give you the behavior you need.*

E.252.1.1. Multiversion Concurrency Control

Because readers in 6.5 don't lock data, regardless of transaction isolation level, data read by one transaction can be overwritten by another. In other words, if a row is returned by `SELECT` it doesn't mean that this row really exists at the time it is returned (i.e. sometime after the statement or transaction began) nor that the row is protected from being deleted or updated by concurrent transactions before the current transaction does a commit or rollback.

To ensure the actual existence of a row and protect it against concurrent updates one must use `SELECT FOR UPDATE` or an appropriate `LOCK TABLE` statement. This should be taken into account when porting applications from previous releases of PostgreSQL and other environments.

Keep the above in mind if you are using `contrib/refint.*` triggers for referential integrity. Additional techniques are required now. One way is to use `LOCK parent_table IN SHARE ROW EXCLUSIVE MODE` command if a transaction is going to update/delete a primary key and use `LOCK parent_table IN SHARE MODE` command if a transaction is going to update/insert a foreign key.

> **Note:** Note that if you run a transaction in SERIALIZABLE mode then you must execute the `LOCK` commands above before execution of any DML statement (`SELECT/INSERT/DELETE/UPDATE/FETCH/COPY_TO`) in the transaction.

These inconveniences will disappear in the future when the ability to read dirty (uncommitted) data (regardless of isolation level) and true referential integrity will be implemented.

E.252.2. Changes

```
Bug Fixes
---------
```

```
Fix text<->float8 and text<->float4 conversion functions(Thomas)
Fix for creating tables with mixed-case constraints(Billy)
Change exp()/pow() behavior to generate error on underflow/overflow(Jan)
Fix bug in pg_dump -z
Memory overrun cleanups(Tatsuo)
Fix for lo_import crash(Tatsuo)
Adjust handling of data type names to suppress double quotes(Thomas)
Use type coercion for matching columns and DEFAULT(Thomas)
Fix deadlock so it only checks once after one second of sleep(Bruce)
Fixes for aggregates and PL/pgsql(Hiroshi)
Fix for subquery crash(Vadim)
Fix for libpq function PQfnumber and case-insensitive names(Bahman Rafatjoo)
Fix for large object write-in-middle, no extra block, memory consumption(Tatsuo)
Fix for pg_dump -d or -D and  quote special characters in INSERT
Repair serious problems with dynahash(Tom)
Fix INET/CIDR portability problems
Fix problem with selectivity error in ALTER TABLE ADD COLUMN(Bruce)
Fix executor so mergejoin of different column types works(Tom)
Fix for Alpha OR selectivity bug
Fix OR index selectivity problem(Bruce)
Fix so \d shows proper length for char()/varchar()(Ryan)
Fix tutorial code(Clark)
Improve destroyuser checking(Oliver)
Fix for Kerberos(Rodney McDuff)
Fix for dropping database while dirty buffers(Bruce)
Fix so sequence nextval() can be case-sensitive(Bruce)
Fix !!= operator
Drop buffers before destroying database files(Bruce)
Fix case where executor evaluates functions twice(Tatsuo)
Allow sequence nextval actions to be case-sensitive(Bruce)
Fix optimizer indexing not working for negative numbers(Bruce)
Fix for memory leak in executor with fjIsNull
Fix for aggregate memory leaks(Erik Riedel)
Allow user name containing a dash to grant privileges
Cleanup of NULL in inet types
Clean up system table bugs(Tom)
Fix problems of PAGER and \? command(Masaaki Sakaida)
Reduce default multisegment file size limit to 1GB(Peter)
Fix for dumping of CREATE OPERATOR(Tom)
Fix for backward scanning of cursors(Hiroshi Inoue)
Fix for COPY FROM STDIN when using \i(Tom)
Fix for subselect is compared inside an expression(Jan)
Fix handling of error reporting while returning rows(Tom)
Fix problems with reference to array types(Tom,Jan)
Prevent UPDATE SET oid(Jan)
Fix pg_dump so -t option can handle case-sensitive tablenames
Fixes for GROUP BY in special cases(Tom, Jan)
Fix for memory leak in failed queries(Tom)
DEFAULT now supports mixed-case identifiers(Tom)
Fix for multisegment uses of DROP/RENAME table, indexes(Ole Gjerde)
Disable use of pg_dump with both -o and -d options(Bruce)
Allow pg_dump to properly dump group privileges(Bruce)
Fix GROUP BY in INSERT INTO table SELECT * FROM table2(Jan)
Fix for computations in views(Jan)
Fix for aggregates on array indexes(Tom)
Fix for DEFAULT handles single quotes in value requiring too many quotes
Fix security problem with non-super users importing/exporting large objects(Tom)
```

```
Rollback of transaction that creates table cleaned up properly(Tom)
Fix to allow long table and column names to generate proper serial names(Tom)

Enhancements
------------
Add "vacuumdb" utility
Speed up libpq by allocating memory better(Tom)
EXPLAIN all indexes used(Tom)
Implement CASE, COALESCE, NULLIF  expression(Thomas)
New pg_dump table output format(Constantin)
Add string min()/max() functions(Thomas)
Extend new type coercion techniques to aggregates(Thomas)
New moddatetime contrib(Terry)
Update to pgaccess 0.96(Constantin)
Add routines for single-byte "char" type(Thomas)
Improved substr() function(Thomas)
Improved multibyte handling(Tatsuo)
Multiversion concurrency control/MVCC(Vadim)
New Serialized mode(Vadim)
Fix for tables over 2gigs(Peter)
New SET TRANSACTION ISOLATION LEVEL(Vadim)
New LOCK TABLE IN ... MODE(Vadim)
Update ODBC driver(Byron)
New NUMERIC data type(Jan)
New SELECT FOR UPDATE(Vadim)
Handle "NaN" and "Infinity" for input values(Jan)
Improved date/year handling(Thomas)
Improved handling of backend connections(Magnus)
New options ELOG_TIMESTAMPS and USE_SYSLOG options for log files(Massimo)
New TCL_ARRAYS option(Massimo)
New INTERSECT and EXCEPT(Stefan)
New pg_index.indisprimary for primary key tracking(D'Arcy)
New pg_dump option to allow dropping of tables before creation(Brook)
Speedup of row output routines(Tom)
New READ COMMITTED isolation level(Vadim)
New TEMP tables/indexes(Bruce)
Prevent sorting if result is already sorted(Jan)
New memory allocation optimization(Jan)
Allow psql to do \p\g(Bruce)
Allow multiple rule actions(Jan)
Added LIMIT/OFFSET functionality(Jan)
Improve optimizer when joining a large number of tables(Bruce)
New intro to SQL from S. Simkovics' Master's Thesis (Stefan, Thomas)
New intro to backend processing from S. Simkovics' Master's Thesis (Stefan)
Improved int8 support(Ryan Bradetich, Thomas, Tom)
New routines to convert between int8 and text/varchar types(Thomas)
New bushy plans, where meta-tables are joined(Bruce)
Enable right-hand queries by default(Bruce)
Allow reliable maximum number of backends to be set at configure time
     (--with-maxbackends and postmaster switch (-N backends))(Tom)
GEQO default now 10 tables because of optimizer speedups(Tom)
Allow NULL=Var for MS-SQL portability(Michael, Bruce)
Modify contrib check_primary_key() so either "automatic" or "dependent"(Anand)
Allow psql \d on a view show query(Ryan)
Speedup for LIKE(Bruce)
Ecpg fixes/features, see src/interfaces/ecpg/ChangeLog file(Michael)
JDBC fixes/features, see src/interfaces/jdbc/CHANGELOG(Peter)
```

```
Make % operator have precedence like /(Bruce)
Add new postgres -O option to allow system table structure changes(Bruce)
Update contrib/pginterface/findoidjoins script(Tom)
Major speedup in vacuum of deleted rows with indexes(Vadim)
Allow non-SQL functions to run different versions based on arguments(Tom)
Add -E option that shows actual queries sent by \dt and friends(Masaaki Sakaida)
Add version number in start-up banners for psql(Masaaki Sakaida)
New contrib/vacuumlo removes large objects not referenced(Peter)
New initialization for table sizes so non-vacuumed tables perform better(Tom)
Improve error messages when a connection is rejected(Tom)
Support for arrays of char() and varchar() fields(Massimo)
Overhaul of hash code to increase reliability and performance(Tom)
Update to PyGreSQL 2.4(D'Arcy)
Changed debug options so -d4 and -d5 produce different node displays(Jan)
New pg_options: pretty_plan, pretty_parse, pretty_rewritten(Jan)
Better optimization statistics for system table access(Tom)
Better handling of non-default block sizes(Massimo)
Improve GEQO optimizer memory consumption(Tom)
UNION now supports ORDER BY of columns not in target list(Jan)
Major libpq++ improvements(Vince Vielhaber)
pg_dump now uses -z(ACL's) as default(Bruce)
backend cache, memory speedups(Tom)
have pg_dump do everything in one snapshot transaction(Vadim)
fix for large object memory leakage, fix for pg_dumping(Tom)
INET type now respects netmask for comparisons
Make VACUUM ANALYZE only use a readlock(Vadim)
Allow VIEWs on UNIONS(Jan)
pg_dump now can generate consistent snapshots on active databases(Vadim)

Source Tree Changes
-------------------
Improve port matching(Tom)
Portability fixes for SunOS
Add Windows NT backend port and enable dynamic loading(Magnus and Daniel Horak)
New port to Cobalt Qube(Mips) running Linux(Tatsuo)
Port to NetBSD/m68k(Mr. Mutsuki Nakajima)
Port to NetBSD/sun3(Mr. Mutsuki Nakajima)
Port to NetBSD/macppc(Toshimi Aoki)
Fix for tcl/tk configuration(Vince)
Removed CURRENT key word for rule queries(Jan)
NT dynamic loading now works(Daniel Horak)
Add ARM32 support(Andrew McMurry)
Better support for HP-UX 11 and UnixWare
Improve file handling to be more uniform, prevent file descriptor leak(Tom)
New install commands for plpgsql(Jan)
```

E.253. Release 6.4.2

Release Date: 1998-12-20

The 6.4.1 release was improperly packaged. This also has one additional bug fix.

E.253.1. Migration to Version 6.4.2

A dump/restore is *not* required for those running 6.4.*.

E.253.2. Changes

```
Fix for datetime constant problem on some platforms(Thomas)
```

E.254. Release 6.4.1

Release Date: 1998-12-18

This is basically a cleanup release for 6.4. We have fixed a variety of problems reported by 6.4 users.

E.254.1. Migration to Version 6.4.1

A dump/restore is *not* required for those running 6.4.

E.254.2. Changes

```
Add pg_dump -N flag to force double quotes around identifiers.  This is
       the default(Thomas)
Fix for NOT in where clause causing crash(Bruce)
EXPLAIN VERBOSE coredump fix(Vadim)
Fix shared-library problems on Linux
Fix test for table existence to allow mixed-case and whitespace in
       the table name(Thomas)
Fix a couple of pg_dump bugs
Configure matches template/.similar entries better(Tom)
Change builtin function names from SPI_* to spi_*
OR WHERE clause fix(Vadim)
Fixes for mixed-case table names(Billy)
contrib/linux/postgres.init.csh/sh fix(Thomas)
libpq memory overrun fix
SunOS fixes(Tom)
Change exp() behavior to generate error on underflow(Thomas)
pg_dump fixes for memory leak, inheritance constraints, layout change
update pgaccess to 0.93
Fix prototype for 64-bit platforms
Multibyte fixes(Tatsuo)
New ecpg man page
```

```
Fix memory overruns(Tatsuo)
Fix for lo_import() crash(Bruce)
Better search for install program(Tom)
Timezone fixes(Tom)
HP-UX fixes(Tom)
Use implicit type coercion for matching DEFAULT values(Thomas)
Add routines to help with single-byte (internal) character type(Thomas)
Compilation of libpq for Windows fixes(Magnus)
Upgrade to PyGreSQL 2.2(D'Arcy)
```

E.255. Release 6.4

Release Date: 1998-10-30

There are *many* new features and improvements in this release. Thanks to our developers and maintainers, nearly every aspect of the system has received some attention since the previous release. Here is a brief, incomplete summary:

- Views and rules are now functional thanks to extensive new code in the rewrite rules system from Jan Wieck. He also wrote a chapter on it for the *Programmer's Guide*.
- Jan also contributed a second procedural language, PL/pgSQL, to go with the original PL/pgTCL procedural language he contributed last release.
- We have optional multiple-byte character set support from Tatsuo Ishii to complement our existing locale support.
- Client/server communications has been cleaned up, with better support for asynchronous messages and interrupts thanks to Tom Lane.
- The parser will now perform automatic type coercion to match arguments to available operators and functions, and to match columns and expressions with target columns. This uses a generic mechanism which supports the type extensibility features of PostgreSQL. There is a new chapter in the *User's Guide* which covers this topic.
- Three new data types have been added. Two types, `inet` and `cidr`, support various forms of IP network, subnet, and machine addressing. There is now an 8-byte integer type available on some platforms. See the chapter on data types in the *User's Guide* for details. A fourth type, `serial`, is now supported by the parser as an amalgam of the `int4` type, a sequence, and a unique index.
- Several more SQL92-compatible syntax features have been added, including `INSERT DEFAULT VALUES`
- The automatic configuration and installation system has received some attention, and should be more robust for more platforms than it has ever been.

E.255.1. Migration to Version 6.4

A dump/restore using pg_dump or pg_dumpall is required for those wishing to migrate data from any previous release of PostgreSQL.

E.255.2. Changes

```
Bug Fixes
---------
Fix for a tiny memory leak in PQsetdb/PQfinish(Bryan)
Remove char2-16 data types, use char/varchar(Darren)
Pqfn not handles a NOTICE message(Anders)
Reduced busywaiting overhead for spinlocks with many backends (dg)
Stuck spinlock detection (dg)
Fix up "ISO-style" timespan decoding and encoding(Thomas)
Fix problem with table drop after rollback of transaction(Vadim)
Change error message and remove non-functional update message(Vadim)
Fix for COPY array checking
Fix for SELECT 1 UNION SELECT NULL
Fix for buffer leaks in large object calls(Pascal)
Change owner from oid to int4 type(Bruce)
Fix a bug in the oracle compatibility functions btrim() ltrim() and rtrim()
Fix for shared invalidation cache overflow(Massimo)
Prevent file descriptor leaks in failed COPY's(Bruce)
Fix memory leak in libpgtcl's pg_select(Constantin)
Fix problems with username/passwords over 8 characters(Tom)
Fix problems with handling of asynchronous NOTIFY in backend(Tom)
Fix of many bad system table entries(Tom)

Enhancements
------------
Upgrade ecpg and ecpglib,see src/interfaces/ecpc/ChangeLog(Michael)
Show the index used in an EXPLAIN(Zeugswetter)
EXPLAIN  invokes  rule system and shows plan(s) for rewritten queries(Jan)
Multibyte awareness of many data types and functions, via configure(Tatsuo)
New configure --with-mb option(Tatsuo)
New initdb --pgencoding option(Tatsuo)
New createdb -E multibyte option(Tatsuo)
Select version(); now returns PostgreSQL version(Jeroen)
libpq now allows asynchronous clients(Tom)
Allow cancel from client of backend query(Tom)
psql now cancels query with Control-C(Tom)
libpq users need not issue dummy queries to get NOTIFY messages(Tom)
NOTIFY now sends sender's PID, so you can tell whether it was your own(Tom)
PGresult struct now includes associated error message, if any(Tom)
Define "tz_hour" and "tz_minute" arguments to date_part()(Thomas)
Add routines to convert between varchar and bpchar(Thomas)
Add routines to allow sizing of varchar and bpchar into target columns(Thomas)
Add bit flags to support timezonehour and minute in data retrieval(Thomas)
Allow more variations on valid floating point numbers (e.g. ".1", "1e6")(Thomas)
Fixes for unary minus parsing with leading spaces(Thomas)
Implement TIMEZONE_HOUR, TIMEZONE_MINUTE per SQL92 specs(Thomas)
Check for and properly ignore FOREIGN KEY column constraints(Thomas)
Define USER as synonym for CURRENT_USER per SQL92 specs(Thomas)
Enable HAVING clause but no fixes elsewhere yet.
```

```
Make "char" type a synonym for "char(1)" (actually implemented as bpchar)(Thomas)
Save string type if specified for DEFAULT clause handling(Thomas)
Coerce operations involving different data types(Thomas)
Allow some index use for columns of different types(Thomas)
Add capabilities for automatic type conversion(Thomas)
Cleanups for large objects, so file is truncated on open(Peter)
Readline cleanups(Tom)
Allow psql  \f \ to make spaces as delimiter(Bruce)
Pass pg_attribute.atttypmod to the frontend for column field lengths(Tom,Bruce)
Msql compatibility library in /contrib(Aldrin)
Remove the requirement that ORDER/GROUP BY clause identifiers be
included in the target list(David)
Convert columns to match columns in UNION clauses(Thomas)
Remove fork()/exec() and only do fork()(Bruce)
Jdbc cleanups(Peter)
Show backend status on ps command line(only works on some platforms)(Bruce)
Pg_hba.conf now has a sameuser option in the database field
Make lo_unlink take oid param, not int4
New DISABLE_COMPLEX_MACRO for compilers that cannot handle our macros(Bruce)
Libpgtcl now handles NOTIFY as a Tcl event, need not send dummy queries(Tom)
libpgtcl cleanups(Tom)
Add -error option to libpgtcl's pg_result command(Tom)
New locale patch, see docs/README/locale(Oleg)
Fix for pg_dump so CONSTRAINT and CHECK syntax is correct(ccb)
New contrib/lo code for large object orphan removal(Peter)
New psql command "SET CLIENT_ENCODING TO 'encoding'" for multibytes
feature, see /doc/README.mb(Tatsuo)
contrib/noupdate code to revoke update permission on a column
libpq can now be compiled on Windows(Magnus)
Add PQsetdbLogin() in libpq
New 8-byte integer type, checked by configure for OS support(Thomas)
Better support for quoted table/column names(Thomas)
Surround table and column names with double-quotes in pg_dump(Thomas)
PQreset() now works with passwords(Tom)
Handle case of GROUP BY target list column number out of range(David)
Allow UNION in subselects
Add auto-size to screen to \d? commands(Bruce)
Use UNION to show all \d? results in one query(Bruce)
Add \d? field search feature(Bruce)
Pg_dump issues fewer \connect requests(Tom)
Make pg_dump -z flag work better, document it in manual page(Tom)
Add HAVING clause with full support for subselects and unions(Stephan)
Full text indexing routines in contrib/fulltextindex(Maarten)
Transaction ids now stored in shared memory(Vadim)
New PGCLIENTENCODING when issuing COPY command(Tatsuo)
Support for SQL92 syntax "SET NAMES"(Tatsuo)
Support for LATIN2-5(Tatsuo)
Add UNICODE regression test case(Tatsuo)
Lock manager cleanup, new locking modes for LLL(Vadim)
Allow index use with OR clauses(Bruce)
Allows "SELECT NULL ORDER BY 1;"
Explain VERBOSE prints the plan, and now pretty-prints the plan to
the postmaster log file(Bruce)
Add indexes display to \d command(Bruce)
Allow GROUP BY on functions(David)
New pg_class.relkind for large objects(Bruce)
New way to send libpq NOTICE messages to a different location(Tom)
```

```
New \w write command to psql(Bruce)
New /contrib/findoidjoins scans oid columns to find join relationships(Bruce)
Allow binary-compatible indexes to be considered when checking for valid
Indexes for restriction clauses containing a constant(Thomas)
New ISBN/ISSN code in /contrib/isbn_issn
Allow NOT LIKE, IN, NOT IN, BETWEEN, and NOT BETWEEN constraint(Thomas)
New rewrite system fixes many problems with rules and views(Jan)
       * Rules on relations work
       * Event qualifications on insert/update/delete work
       * New OLD variable to reference CURRENT, CURRENT will be remove in future
       * Update rules can reference NEW and OLD in rule qualifications/actions
       * Insert/update/delete rules on views work
       * Multiple rule actions are now supported, surrounded by parentheses
       * Regular users can create views/rules on tables they have RULE permits
       * Rules and views inherit the privileges of the creator
       * No rules at the column level
       * No UPDATE NEW/OLD rules
       * New pg_tables, pg_indexes, pg_rules and pg_views system views
       * Only a single action on SELECT rules
       * Total rewrite overhaul, perhaps for 6.5
       * handle subselects
       * handle aggregates on views
       * handle insert into select from view works
System indexes are now multikey(Bruce)
Oidint2, oidint4, and oidname types are removed(Bruce)
Use system cache for more system table lookups(Bruce)
New backend programming language PL/pgSQL in backend/pl(Jan)
New SERIAL data type, auto-creates sequence/index(Thomas)
Enable assert checking without a recompile(Massimo)
User lock enhancements(Massimo)
New setval() command to set sequence value(Massimo)
Auto-remove unix socket file on start-up if no postmaster running(Massimo)
Conditional trace package(Massimo)
New UNLISTEN command(Massimo)
psql and libpq now compile under Windows using win32.mak(Magnus)
Lo_read no longer stores trailing NULL(Bruce)
Identifiers are now truncated to 31 characters internally(Bruce)
Createuser options now available on the command line
Code for 64-bit integer supported added, configure tested, int8 type(Thomas)
Prevent file descriptor leaf from failed COPY(Bruce)
New pg_upgrade command(Bruce)
Updated /contrib directories(Massimo)
New CREATE TABLE DEFAULT VALUES statement available(Thomas)
New INSERT INTO TABLE DEFAULT VALUES statement available(Thomas)
New DECLARE and FETCH feature(Thomas)
libpq's internal structures now not exported(Tom)
Allow up to 8 key indexes(Bruce)
Remove ARCHIVE key word, that is no longer used(Thomas)
pg_dump -n flag to suppress quotes around identifiers
disable system columns for views(Jan)
new INET and CIDR types for network addresses(TomH, Paul)
no more double quotes in psql output
pg_dump now dumps views(Terry)
new SET QUERY_LIMIT(Tatsuo,Jan)

Source Tree Changes
-------------------
```

```
/contrib cleanup(Jun)
Inline some small functions called for every row(Bruce)
Alpha/linux fixes
HP-UX cleanups(Tom)
Multibyte regression tests(Soonmyung.)
Remove --disabled options from configure
Define PGDOC to use POSTGRESDIR by default
Make regression optional
Remove extra braces code to pgindent(Bruce)
Add bsdi shared library support(Bruce)
New --without-CXX support configure option(Brook)
New FAQ_CVS
Update backend flowchart in tools/backend(Bruce)
Change atttypmod from int16 to int32(Bruce, Tom)
Getrusage() fix for platforms that do not have it(Tom)
Add PQconnectdb, PGUSER, PGPASSWORD to libpq man page
NS32K platform fixes(Phil Nelson, John Buller)
SCO 7/UnixWare 2.x fixes(Billy,others)
Sparc/Solaris 2.5 fixes(Ryan)
Pgbuiltin.3 is obsolete, move to doc files(Thomas)
Even more documentation(Thomas)
Nextstep support(Jacek)
Aix support(David)
pginterface manual page(Bruce)
shared libraries all have version numbers
merged all OS-specific shared library defines into one file
smarter TCL/TK configuration checking(Billy)
smarter perl configuration(Brook)
configure uses supplied install-sh if no install script found(Tom)
new Makefile.shlib for shared library configuration(Tom)
```

E.256. Release 6.3.2

Release Date: 1998-04-07

This is a bug-fix release for 6.3.x. Refer to the release notes for version 6.3 for a more complete summary of new features.

Summary:

- Repairs automatic configuration support for some platforms, including Linux, from breakage inadvertently introduced in version 6.3.1.
- Correctly handles function calls on the left side of BETWEEN and LIKE clauses.

A dump/restore is NOT required for those running 6.3 or 6.3.1. A `make distclean`, `make`, and `make install` is all that is required. This last step should be performed while the postmaster is not running. You should re-link any custom applications that use PostgreSQL libraries.

For upgrades from pre-6.3 installations, refer to the installation and migration instructions for version 6.3.

E.256.1. Changes

```
Configure detection improvements for tcl/tk(Brook Milligan, Alvin)
Manual page improvements(Bruce)
BETWEEN and LIKE fix(Thomas)
fix for psql \connect used by pg_dump(Oliver Elphick)
New odbc driver
pgaccess, version 0.86
qsort removed, now uses libc version, cleanups(Jeroen)
fix for buffer over-runs detected(Maurice Gittens)
fix for buffer overrun in libpgtcl(Randy Kunkee)
fix for UNION with DISTINCT or ORDER BY(Bruce)
gettimeofday configure check(Doug Winterburn)
Fix "indexes not used" bug(Vadim)
docs additions(Thomas)
Fix for backend memory leak(Bruce)
libreadline cleanup(Erwan MAS)
Remove DISTDIR(Bruce)
Makefile dependency cleanup(Jeroen van Vianen)
ASSERT fixes(Bruce)
```

E.257. Release 6.3.1

Release Date: 1998-03-23

Summary:

- Additional support for multibyte character sets.
- Repair byte ordering for mixed-endian clients and servers.
- Minor updates to allowed SQL syntax.
- Improvements to the configuration autodetection for installation.

A dump/restore is NOT required for those running 6.3. A `make distclean`, `make`, and `make install` is all that is required. This last step should be performed while the postmaster is not running. You should re-link any custom applications that use PostgreSQL libraries.

For upgrades from pre-6.3 installations, refer to the installation and migration instructions for version 6.3.

E.257.1. Changes

```
ecpg cleanup/fixes, now version 1.1(Michael Meskes)
pg_user cleanup(Bruce)
large object fix for pg_dump and tclsh (alvin)
LIKE fix for multiple adjacent underscores
fix for redefining builtin functions(Thomas)
ultrix4 cleanup
upgrade to pg_access 0.83
updated CLUSTER manual page
multibyte character set support, see doc/README.mb(Tatsuo)
configure --with-pgport fix
pg_ident fix
big-endian fix for backend communications(Kataoka)
SUBSTR() and substring() fix(Jan)
several jdbc fixes(Peter)
libpgtcl improvements, see libptcl/README(Randy Kunkee)
Fix for "Datasize = 0" error(Vadim)
Prevent \do from wrapping(Bruce)
Remove duplicate Russian character set entries
Sunos4 cleanup
Allow optional TABLE key word in LOCK and SELECT INTO(Thomas)
CREATE SEQUENCE options to allow a negative integer(Thomas)
Add "PASSWORD" as an allowed column identifier(Thomas)
Add checks for UNION target fields(Bruce)
Fix Alpha port(Dwayne Bailey)
Fix for text arrays containing quotes(Doug Gibson)
Solaris compile fix(Albert Chin-A-Young)
Better identify tcl and tk libs and includes(Bruce)
```

E.258. Release 6.3

Release Date: 1998-03-01

There are *many* new features and improvements in this release. Here is a brief, incomplete summary:

- Many new SQL features, including full SQL92 subselect capability (everything is here but target-list subselects).
- Support for client-side environment variables to specify time zone and date style.
- Socket interface for client/server connection. This is the default now so you might need to start postmaster with the `-i` flag.
- Better password authorization mechanisms. Default table privileges have changed.
- Old-style *time travel* has been removed. Performance has been improved.

Note: Bruce Momjian wrote the following notes to introduce the new release.

There are some general 6.3 issues that I want to mention. These are only the big items that cannot be described in one sentence. A review of the detailed changes list is still needed.

First, we now have subselects. Now that we have them, I would like to mention that without subselects, SQL is a very limited language. Subselects are a major feature, and you should review your code for places where subselects provide a better solution for your queries. I think you will find that there are more uses for subselects than you might think. Vadim has put us on the big SQL map with subselects, and fully functional ones too. The only thing you cannot do with subselects is to use them in the target list.

Second, 6.3 uses Unix domain sockets rather than TCP/IP by default. To enable connections from other machines, you have to use the new postmaster -i option, and of course edit `pg_hba.conf`. Also, for this reason, the format of `pg_hba.conf` has changed.

Third, `char()` fields will now allow faster access than `varchar()` or `text`. Specifically, the `text` and `varchar()` have a penalty for access to any columns after the first column of this type. `char()` used to also have this access penalty, but it no longer does. This might suggest that you redesign some of your tables, especially if you have short character columns that you have defined as `varchar()` or `text`. This and other changes make 6.3 even faster than earlier releases.

We now have passwords definable independent of any Unix file. There are new SQL USER commands. See the *Administrator's Guide* for more information. There is a new table, pg_shadow, which is used to store user information and user passwords, and it by default only SELECT-able by the postgres super-user. pg_user is now a view of pg_shadow, and is SELECT-able by PUBLIC. You should keep using pg_user in your application without changes.

User-created tables now no longer have SELECT privilege to PUBLIC by default. This was done because the ANSI standard requires it. You can of course GRANT any privileges you want after the table is created. System tables continue to be SELECT-able by PUBLIC.

We also have real deadlock detection code. No more sixty-second timeouts. And the new locking code implements a FIFO better, so there should be less resource starvation during heavy use.

Many complaints have been made about inadequate documentation in previous releases. Thomas has put much effort into many new manuals for this release. Check out the doc/ directory.

For performance reasons, time travel is gone, but can be implemented using triggers (see `pgsql/contrib/spi/README`). Please check out the new \d command for types, operators, etc. Also, views have their own privileges now, not based on the underlying tables, so privileges on them have to be set separately. Check `/pgsql/interfaces` for some new ways to talk to PostgreSQL.

This is the first release that really required an explanation for existing users. In many ways, this was necessary because the new release removes many limitations, and the work-arounds people were using are no longer needed.

E.258.1. Migration to Version 6.3

A dump/restore using pg_dump or pg_dumpall is required for those wishing to migrate data from any previous release of PostgreSQL.

E.258.2. Changes

```
Bug Fixes
---------
Fix binary cursors broken by MOVE implementation(Vadim)
Fix for tcl library crash(Jan)
Fix for array handling, from Gerhard Hintermayer
Fix acl error, and remove duplicate pqtrace(Bruce)
Fix psql \e for empty file(Bruce)
Fix for textcat on varchar() fields(Bruce)
Fix for DBT Sendproc (Zeugswetter Andres)
Fix vacuum analyze syntax problem(Bruce)
Fix for international identifiers(Tatsuo)
Fix aggregates on inherited tables(Bruce)
Fix substr() for out-of-bounds data
Fix for select 1=1 or 2=2, select 1=1 and 2=2, and select sum(2+2)(Bruce)
Fix notty output to show status result.  -q option still turns it off(Bruce)
Fix for count(*), aggs with views and multiple tables and sum(3)(Bruce)
Fix cluster(Bruce)
Fix for PQtrace start/stop several times(Bruce)
Fix a variety of locking problems like newer lock waiters getting
       lock before older waiters, and having readlock people not share
       locks if a writer is waiting for a lock, and waiting writers not
       getting priority over waiting readers(Bruce)
Fix crashes in psql when executing queries from external files(James)
Fix problem with multiple order by columns, with the first one having
       NULL values(Jeroen)
Use correct hash table support functions for float8 and int4(Thomas)
Re-enable JOIN= option in CREATE OPERATOR statement (Thomas)
Change precedence for boolean operators to match expected behavior(Thomas)
Generate elog(ERROR) on over-large integer(Bruce)
Allow multiple-argument functions in constraint clauses(Thomas)
Check boolean input literals for 'true','false','yes','no','1','0'
       and throw elog(ERROR) if unrecognized(Thomas)
Major large objects fix
Fix for GROUP BY showing duplicates(Vadim)
Fix for index scans in MergeJoin(Vadim)

Enhancements
------------
Subselects with EXISTS, IN, ALL, ANY key words (Vadim, Bruce, Thomas)
New User Manual(Thomas, others)
Speedup by inlining some frequently-called functions
Real deadlock detection, no more timeouts(Bruce)
Add SQL92 "constants" CURRENT_DATE, CURRENT_TIME, CURRENT_TIMESTAMP,
       CURRENT_USER(Thomas)
Modify constraint syntax to be SQL92-compliant(Thomas)
Implement SQL92 PRIMARY KEY and UNIQUE clauses using indexes(Thomas)
Recognize SQL92 syntax for FOREIGN KEY. Throw elog notice(Thomas)
Allow NOT NULL UNIQUE constraint clause (each allowed separately before)(Thomas)
Allow PostgreSQL-style casting ("::") of non-constants(Thomas)
Add support for SQL3 TRUE and FALSE boolean constants(Thomas)
Support SQL92 syntax for IS TRUE/IS FALSE/IS NOT TRUE/IS NOT FALSE(Thomas)
Allow shorter strings for boolean literals (e.g. "t", "tr", "tru")(Thomas)
Allow SQL92 delimited identifiers(Thomas)
Implement SQL92 binary and hexadecimal string decoding (b'10' and x'1F')(Thomas)
Support SQL92 syntax for type coercion of literal strings
```

```
       (e.g. "DATETIME 'now'")(Thomas)
Add conversions for int2, int4, and OID types to and from text(Thomas)
Use shared lock when building indexes(Vadim)
Free memory allocated for a user query inside transaction block after
       this query is done, was turned off in <= 6.2.1(Vadim)
New SQL statement CREATE PROCEDURAL LANGUAGE(Jan)
New PostgreSQL Procedural Language (PL) backend interface(Jan)
Rename pg_dump -H option to -h(Bruce)
Add Java support for passwords, European dates(Peter)
Use indexes for LIKE and ~, !~ operations(Bruce)
Add hash functions for datetime and timespan(Thomas)
Time Travel removed(Vadim, Bruce)
Add paging for \d and \z, and fix \i(Bruce)
Add Unix domain socket support to backend and to frontend library(Goran)
Implement CREATE DATABASE/WITH LOCATION and initlocation utility(Thomas)
Allow more SQL92 and/or PostgreSQL reserved words as column identifiers(Thomas)
Augment support for SQL92 SET TIME ZONE...(Thomas)
SET/SHOW/RESET TIME ZONE uses TZ backend environment variable(Thomas)
Implement SET keyword = DEFAULT and SET TIME ZONE DEFAULT(Thomas)
Enable SET TIME ZONE using TZ environment variable(Thomas)
Add PGDATESTYLE environment variable to frontend and backend initialization(Thomas)
Add PGTZ, PGCOSTHEAP, PGCOSTINDEX, PGRPLANS, PGGEQO
       frontend library initialization environment variables(Thomas)
Regression tests time zone automatically set with "setenv PGTZ PST8PDT"(Thomas)
Add pg_description table for info on tables, columns, operators, types, and
       aggregates(Bruce)
Increase 16 char limit on system table/index names to 32 characters(Bruce)
Rename system indexes(Bruce)
Add 'GERMAN' option to SET DATESTYLE(Thomas)
Define an "ISO-style" timespan output format with "hh:mm:ss" fields(Thomas)
Allow fractional values for delta times (e.g. '2.5 days')(Thomas)
Validate numeric input more carefully for delta times(Thomas)
Implement day of year as possible input to date_part()(Thomas)
Define timespan_finite() and text_timespan() functions(Thomas)
Remove archive stuff(Bruce)
Allow for a pg_password authentication database that is separate from
       the system password file(Todd)
Dump ACLs, GRANT, REVOKE privileges(Matt)
Define text, varchar, and bpchar string length functions(Thomas)
Fix Query handling for inheritance, and cost computations(Bruce)
Implement CREATE TABLE/AS SELECT (alternative to SELECT/INTO)(Thomas)
Allow NOT, IS NULL, IS NOT NULL in constraints(Thomas)
Implement UNIONs for SELECT(Bruce)
Add UNION, GROUP, DISTINCT to INSERT(Bruce)
varchar() stores only necessary bytes on disk(Bruce)
Fix for BLOBs(Peter)
Mega-Patch for JDBC...see README_6.3 for list of changes(Peter)
Remove unused "option" from PQconnectdb()
New LOCK command and lock manual page describing deadlocks(Bruce)
Add new psql \da, \dd, \df, \do, \dS, and \dT commands(Bruce)
Enhance psql \z to show sequences(Bruce)
Show NOT NULL and DEFAULT in psql \d table(Bruce)
New psql .psqlrc file start-up(Andrew)
Modify sample start-up script in contrib/linux to show syslog(Thomas)
New types for IP and MAC addresses in contrib/ip_and_mac(TomH)
Unix system time conversions with date/time types in contrib/unixdate(Thomas)
Update of contrib stuff(Massimo)
```

```
Add Unix socket support to DBD::Pg(Goran)
New python interface (PyGreSQL 2.0)(D'Arcy)
New frontend/backend protocol has a version number, network byte order(Phil)
Security features in pg_hba.conf enhanced and documented, many cleanups(Phil)
CHAR() now faster access than VARCHAR() or TEXT
ecpg embedded SQL preprocessor
Reduce system column overhead(Vadmin)
Remove pg_time table(Vadim)
Add pg_type attribute to identify types that need length (bpchar, varchar)
Add report of offending line when COPY command fails
Allow VIEW privileges to be set separately from the underlying tables.
       For security, use GRANT/REVOKE on views as appropriate(Jan)
Tables now have no default GRANT SELECT TO PUBLIC.  You must
       explicitly grant such privileges.
Clean up tutorial examples(Darren)

Source Tree Changes
-------------------
Add new html development tools, and flow chart in /tools/backend
Fix for SCO compiles
Stratus computer port Robert Gillies
Added support for shlib for BSD44_derived & i386_solaris
Make configure more automated(Brook)
Add script to check regression test results
Break parser functions into smaller files, group together(Bruce)
Rename heap_create to heap_create_and_catalog, rename heap_creatr
       to heap_create()(Bruce)
Sparc/Linux patch for locking(TomS)
Remove PORTNAME and reorganize port-specific stuff(Marc)
Add optimizer README file(Bruce)
Remove some recursion in optimizer and clean up some code there(Bruce)
Fix for NetBSD locking(Henry)
Fix for libptcl make(Tatsuo)
AIX patch(Darren)
Change IS TRUE, IS FALSE, ... to expressions using "=" rather than
       function calls to istrue() or isfalse() to allow optimization(Thomas)
Various fixes NetBSD/Sparc related(TomH)
Alpha linux locking(Travis,Ryan)
Change elog(WARN) to elog(ERROR)(Bruce)
FAQ for FreeBSD(Marc)
Bring in the PostODBC source tree as part of our standard distribution(Marc)
A minor patch for HP/UX 10 vs 9(Stan)
New pg_attribute.atttypmod for type-specific info like varchar length(Bruce)
UnixWare patches(Billy)
New i386 'lock' for spinlock asm(Billy)
Support for multiplexed backends is removed
Start an OpenBSD port
Start an AUX port
Start a Cygnus port
Add string functions to regression suite(Thomas)
Expand a few function names formerly truncated to 16 characters(Thomas)
Remove un-needed malloc() calls and replace with palloc()(Bruce)
```

E.259. Release 6.2.1

Release Date: 1997-10-17

6.2.1 is a bug-fix and usability release on 6.2.

Summary:

- Allow strings to span lines, per SQL92.
- Include example trigger function for inserting user names on table updates.

This is a minor bug-fix release on 6.2. For upgrades from pre-6.2 systems, a full dump/reload is required. Refer to the 6.2 release notes for instructions.

E.259.1. Migration from version 6.2 to version 6.2.1

This is a minor bug-fix release. A dump/reload is not required from version 6.2, but is required from any release prior to 6.2.

In upgrading from version 6.2, if you choose to dump/reload you will find that avg(money) is now calculated correctly. All other bug fixes take effect upon updating the executables.

Another way to avoid dump/reload is to use the following SQL command from `psql` to update the existing system table:

```
update pg_aggregate set aggfinalfn = 'cash_div_flt8'
 where aggname = 'avg' and aggbasetype = 790;
```

This will need to be done to every existing database, including template1.

E.259.2. Changes

```
Allow TIME and TYPE column names(Thomas)
Allow larger range of true/false as boolean values(Thomas)
Support output of "now" and "current"(Thomas)
Handle DEFAULT with INSERT of NULL properly(Vadim)
Fix for relation reference counts problem in buffer manager(Vadim)
Allow strings to span lines, like ANSI(Thomas)
Fix for backward cursor with ORDER BY(Vadim)
Fix avg(cash) computation(Thomas)
Fix for specifying a column twice in ORDER/GROUP BY(Vadim)
Documented new libpq function to return affected rows, PQcmdTuples(Bruce)
Trigger function for inserting user names for INSERT/UPDATE(Brook Milligan)
```

E.260. Release 6.2

Release Date: 1997-10-02

A dump/restore is required for those wishing to migrate data from previous releases of PostgreSQL.

E.260.1. Migration from version 6.1 to version 6.2

This migration requires a complete dump of the 6.1 database and a restore of the database in 6.2.

Note that the `pg_dump` and `pg_dumpall` utility from 6.2 should be used to dump the 6.1 database.

E.260.2. Migration from version 1.*x* to version 6.2

Those migrating from earlier 1.* releases should first upgrade to 1.09 because the COPY output format was improved from the 1.02 release.

E.260.3. Changes

```
Bug Fixes
---------
Fix problems with pg_dump for inheritance, sequences, archive tables(Bruce)
Fix compile errors on overflow due to shifts, unsigned, and bad prototypes
        from Solaris(Diab Jerius)
Fix bugs in geometric line arithmetic (bad intersection calculations)(Thomas)
Check for geometric intersections at endpoints to avoid rounding ugliness(Thomas)
Catch non-functional delete attempts(Vadim)
Change time function names to be more consistent(Michael Reifenberg)
Check for zero divides(Michael Reifenberg)
Fix very old bug which made rows changed/inserted by a command
       visible to the command itself (so we had multiple update of
       updated rows, etc.)(Vadim)
Fix for SELECT null, 'fail' FROM pg_am (Patrick)
SELECT NULL as EMPTY_FIELD now allowed(Patrick)
Remove un-needed signal stuff from contrib/pginterface
Fix OR (where x != 1 or x isnull didn't return rows with x NULL) (Vadim)
Fix time_cmp function (Vadim)
Fix handling of functions with non-attribute first argument in
       WHERE clauses (Vadim)
Fix GROUP BY when order of entries is different from order
       in target list (Vadim)
Fix pg_dump for aggregates without sfunc1 (Vadim)

Enhancements
------------
Default genetic optimizer GEQO parameter is now 8(Bruce)
Allow use parameters in target list having aggregates in functions(Vadim)
Added JDBC driver as an interface(Adrian & Peter)
pg_password utility
Return number of rows inserted/affected by INSERT/UPDATE/DELETE etc.(Vadim)
```

```
Triggers implemented with CREATE TRIGGER (SQL3)(Vadim)
SPI (Server Programming Interface) allows execution of queries inside
       C-functions (Vadim)
NOT NULL implemented (SQL92)(Robson Paniago de Miranda)
Include reserved words for string handling, outer joins, and unions(Thomas)
Implement extended comments ("/* ... */") using exclusive states(Thomas)
Add "//" single-line comments(Bruce)
Remove some restrictions on characters in operator names(Thomas)
DEFAULT and CONSTRAINT for tables implemented (SQL92)(Vadim & Thomas)
Add text concatenation operator and function (SQL92)(Thomas)
Support WITH TIME ZONE syntax (SQL92)(Thomas)
Support INTERVAL unit TO unit syntax (SQL92)(Thomas)
Define types DOUBLE PRECISION, INTERVAL, CHARACTER,
       and CHARACTER VARYING (SQL92)(Thomas)
Define type FLOAT(p) and rudimentary DECIMAL(p,s), NUMERIC(p,s) (SQL92)(Thomas)
Define EXTRACT(), POSITION(), SUBSTRING(), and TRIM() (SQL92)(Thomas)
Define CURRENT_DATE, CURRENT_TIME, CURRENT_TIMESTAMP (SQL92)(Thomas)
Add syntax and warnings for UNION, HAVING, INNER and OUTER JOIN (SQL92)(Thomas)
Add more reserved words, mostly for SQL92 compliance(Thomas)
Allow hh:mm:ss time entry for timespan/reltime types(Thomas)
Add center() routines for lseg, path, polygon(Thomas)
Add distance() routines for circle-polygon, polygon-polygon(Thomas)
Check explicitly for points and polygons contained within polygons
       using an axis-crossing algorithm(Thomas)
Add routine to convert circle-box(Thomas)
Merge conflicting operators for different geometric data types(Thomas)
Replace distance operator "<===>" with "<->"(Thomas)
Replace "above" operator "!^" with ">^" and "below" operator "!|" with "<^"(Thomas)
Add routines for text trimming on both ends, substring, and string position(Thomas)
Added conversion routines circle(box) and poly(circle)(Thomas)
Allow internal sorts to be stored in memory rather than in files(Bruce & Vadim)
Allow functions and operators on internally-identical types to succeed(Bruce)
Speed up backend start-up after profiling analysis(Bruce)
Inline frequently called functions for performance(Bruce)
Reduce open() calls(Bruce)
psql:  Add PAGER for \h and \?,\C fix
Fix for psql pager when no tty(Bruce)
New entab utility(Bruce)
General trigger functions for referential integrity (Vadim)
General trigger functions for time travel (Vadim)
General trigger functions for AUTOINCREMENT/IDENTITY feature (Vadim)
MOVE implementation (Vadim)

Source Tree Changes
-------------------
HP-UX 10 patches (Vladimir Turin)
Added SCO support, (Daniel Harris)
MkLinux patches (Tatsuo Ishii)
Change geometric box terminology from "length" to "width"(Thomas)
Deprecate temporary unstored slope fields in geometric code(Thomas)
Remove restart instructions from INSTALL(Bruce)
Look in /usr/ucb first for install(Bruce)
Fix c++ copy example code(Thomas)
Add -o to psql manual page(Bruce)
Prevent relname unallocated string length from being copied into database(Bruce)
Cleanup for NAMEDATALEN use(Bruce)
Fix pg_proc names over 15 chars in output(Bruce)
```

```
Add strNcpy() function(Bruce)
remove some (void) casts that are unnecessary(Bruce)
new interfaces directory(Marc)
Replace fopen() calls with calls to fd.c functions(Bruce)
Make functions static where possible(Bruce)
enclose unused functions in #ifdef NOT_USED(Bruce)
Remove call to difftime() in timestamp support to fix SunOS(Bruce & Thomas)
Changes for Digital Unix
Portability fix for pg_dumpall(Bruce)
Rename pg_attribute.attnvals to attdispersion(Bruce)
"intro/unix" manual page now "pgintro"(Bruce)
"built-in" manual page now "pgbuiltin"(Bruce)
"drop" manual page now "drop_table"(Bruce)
Add "create_trigger", "drop_trigger" manual pages(Thomas)
Add constraints regression test(Vadim & Thomas)
Add comments syntax regression test(Thomas)
Add PGINDENT and support program(Bruce)
Massive commit to run PGINDENT on all *.c and *.h files(Bruce)
Files moved to /src/tools directory(Bruce)
SPI and Trigger programming guides (Vadim & D'Arcy)
```

E.261. Release 6.1.1

Release Date: 1997-07-22

E.261.1. Migration from version 6.1 to version 6.1.1

This is a minor bug-fix release. A dump/reload is not required from version 6.1, but is required from any release prior to 6.1. Refer to the release notes for 6.1 for more details.

E.261.2. Changes

```
fix for SET with options (Thomas)
allow pg_dump/pg_dumpall to preserve ownership of all tables/objects(Bruce)
new psql \connect option allows changing usernames without changing databases
fix for initdb --debug option(Yoshihiko Ichikawa))
lextest cleanup(Bruce)
hash fixes(Vadim)
fix date/time month boundary arithmetic(Thomas)
fix timezone daylight handling for some ports(Thomas, Bruce, Tatsuo)
timestamp overhauled to use standard functions(Thomas)
other code cleanup in date/time routines(Thomas)
psql's \d now case-insensitive(Bruce)
psql's backslash commands can now have trailing semicolon(Bruce)
fix memory leak in psql when using \g(Bruce)
major fix for endian handling of communication to server(Thomas, Tatsuo)
```

```
Fix for Solaris assembler and include files(Yoshihiko Ichikawa)
allow underscores in usernames(Bruce)
pg_dumpall now returns proper status, portability fix(Bruce)
```

E.262. Release 6.1

Release Date: 1997-06-08

The regression tests have been adapted and extensively modified for the 6.1 release of PostgreSQL.

Three new data types (`datetime`, `timespan`, and `circle`) have been added to the native set of PostgreSQL types. Points, boxes, paths, and polygons have had their output formats made consistent across the data types. The polygon output in misc.out has only been spot-checked for correctness relative to the original regression output.

PostgreSQL 6.1 introduces a new, alternate optimizer which uses *genetic* algorithms. These algorithms introduce a random behavior in the ordering of query results when the query contains multiple qualifiers or multiple tables (giving the optimizer a choice on order of evaluation). Several regression tests have been modified to explicitly order the results, and hence are insensitive to optimizer choices. A few regression tests are for data types which are inherently unordered (e.g. points and time intervals) and tests involving those types are explicitly bracketed with `set geqo to 'off'` and `reset geqo`.

The interpretation of array specifiers (the curly braces around atomic values) appears to have changed sometime after the original regression tests were generated. The current `./expected/*.out` files reflect this new interpretation, which might not be correct!

The float8 regression test fails on at least some platforms. This is due to differences in implementations of `pow()` and `exp()` and the signaling mechanisms used for overflow and underflow conditions.

The "random" results in the random test should cause the "random" test to be "failed", since the regression tests are evaluated using a simple diff. However, "random" does not seem to produce random results on my test machine (Linux/gcc/i686).

E.262.1. Migration to Version 6.1

This migration requires a complete dump of the 6.0 database and a restore of the database in 6.1.

Those migrating from earlier 1.* releases should first upgrade to 1.09 because the COPY output format was improved from the 1.02 release.

E.262.2. Changes

```
Bug Fixes
---------
packet length checking in library routines
lock manager priority patch
check for under/over flow of float8(Bruce)
```

```
multitable join fix(Vadim)
SIGPIPE crash fix(Darren)
large object fixes(Sven)
allow btree indexes to handle NULLs(Vadim)
timezone fixes(D'Arcy)
select SUM(x) can return NULL on no rows(Thomas)
internal optimizer, executor bug fixes(Vadim)
fix problem where inner loop in < or <= has no rows(Vadim)
prevent re-commuting join index clauses(Vadim)
fix join clauses for multiple tables(Vadim)
fix hash, hashjoin for arrays(Vadim)
fix btree for abstime type(Vadim)
large object fixes(Raymond)
fix buffer leak in hash indexes (Vadim)
fix rtree for use in inner scan (Vadim)
fix gist for use in inner scan, cleanups (Vadim, Andrea)
avoid unnecessary local buffers allocation (Vadim, Massimo)
fix local buffers leak in transaction aborts (Vadim)
fix file manager memmory leaks, cleanups (Vadim, Massimo)
fix storage manager memmory leaks (Vadim)
fix btree duplicates handling (Vadim)
fix deleted rows reincarnation caused by vacuum (Vadim)
fix SELECT varchar()/char() INTO TABLE made zero-length fields(Bruce)
many psql, pg_dump, and libpq memory leaks fixed using Purify (Igor)

Enhancements
------------
attribute optimization statistics(Bruce)
much faster new btree bulk load code(Paul)
BTREE UNIQUE added to bulk load code(Vadim)
new lock debug code(Massimo)
massive changes to libpg++(Leo)
new GEQO optimizer speeds table multitable optimization(Martin)
new WARN message for non-unique insert into unique key(Marc)
update x=-3, no spaces, now valid(Bruce)
remove case-sensitive identifier handling(Bruce,Thomas,Dan)
debug backend now pretty-prints tree(Darren)
new Oracle character functions(Edmund)
new plaintext password functions(Dan)
no such class or insufficient privilege changed to distinct messages(Dan)
new ANSI timestamp function(Dan)
new ANSI Time and Date types (Thomas)
move large chunks of data in backend(Martin)
multicolumn btree indexes(Vadim)
new SET var TO value command(Martin)
update transaction status on reads(Dan)
new locale settings for character types(Oleg)
new SEQUENCE serial number generator(Vadim)
GROUP BY function now possible(Vadim)
re-organize regression test(Thomas,Marc)
new optimizer operation weights(Vadim)
new psql \z grant/permit option(Marc)
new MONEY data type(D'Arcy,Thomas)
tcp socket communication speed improved(Vadim)
new VACUUM option for attribute statistics, and for certain columns (Vadim)
many geometric type improvements(Thomas,Keith)
additional regression tests(Thomas)
```

```
new datestyle variable(Thomas,Vadim,Martin)
more comparison operators for sorting types(Thomas)
new conversion functions(Thomas)
new more compact btree format(Vadim)
allow pg_dumpall to preserve database ownership(Bruce)
new SET GEQO=# and R_PLANS variable(Vadim)
old (!GEQO) optimizer can use right-sided plans (Vadim)
typechecking improvement in SQL parser(Bruce)
new SET, SHOW, RESET commands(Thomas,Vadim)
new \connect database USER option
new destroydb -i option (Igor)
new \dt and \di psql commands (Darren)
SELECT "\n" now escapes newline (A. Duursma)
new geometry conversion functions from old format (Thomas)

Source tree changes
-------------------
new configuration script(Marc)
readline configuration option added(Marc)
OS-specific configuration options removed(Marc)
new OS-specific template files(Marc)
no more need to edit Makefile.global(Marc)
re-arrange include files(Marc)
nextstep patches (Gregor Hoffleit)
removed Windows-specific code(Bruce)
removed postmaster -e option, now only postgres -e option (Bruce)
merge duplicate library code in front/backends(Martin)
now works with eBones, international Kerberos(Jun)
more shared library support
c++ include file cleanup(Bruce)
warn about buggy flex(Bruce)
DG/UX, Ultrix, IRIX, AIX portability fixes
```

E.263. Release 6.0

Release Date: 1997-01-29

A dump/restore is required for those wishing to migrate data from previous releases of PostgreSQL.

E.263.1. Migration from version 1.09 to version 6.0

This migration requires a complete dump of the 1.09 database and a restore of the database in 6.0.

E.263.2. Migration from pre-1.09 to version 6.0

Those migrating from earlier 1.* releases should first upgrade to 1.09 because the COPY output format was improved from the 1.02 release.

E.263.3. Changes

```
Bug Fixes
---------
ALTER TABLE bug - running postgres process needs to re-read table definition
Allow vacuum to be run on one table or entire database(Bruce)
Array fixes
Fix array over-runs of memory writes(Kurt)
Fix elusive btree range/non-range bug(Dan)
Fix for hash indexes on some types like time and date
Fix for pg_log size explosion
Fix permissions on lo_export()(Bruce)
Fix uninitialized reads of memory(Kurt)
Fixed ALTER TABLE ... char(3) bug(Bruce)
Fixed a few small memory leaks
Fixed EXPLAIN handling of options and changed full_path option name
Fixed output of group acl privileges
Memory leaks (hunt and destroy with tools like Purify(Kurt)
Minor improvements to rules system
NOTIFY fixes
New asserts for run-checking
Overhauled parser/analyze code to properly report errors and increase speed
Pg_dump -d now handles NULL's properly(Bruce)
Prevent SELECT NULL from crashing server (Bruce)
Properly report errors when INSERT ... SELECT columns did not match
Properly report errors when insert column names were not correct
psql \g filename now works(Bruce)
psql fixed problem with multiple statements on one line with multiple outputs
Removed duplicate system OIDs
SELECT * INTO TABLE . GROUP/ORDER BY gives unlink error if table exists(Bruce)
Several fixes for queries that crashed the backend
Starting quote in insert string errors(Bruce)
Submitting an empty query now returns empty status, not just " " query(Bruce)

Enhancements
------------
Add EXPLAIN manual page(Bruce)
Add UNIQUE index capability(Dan)
Add hostname/user level access control rather than just hostname and user
Add synonym of != for <>(Bruce)
Allow "select oid,* from table"
Allow BY,ORDER BY to specify columns by number, or by non-alias table.column(Bruce)
Allow COPY from the frontend(Bryan)
Allow GROUP BY to use alias column name(Bruce)
Allow actual compression, not just reuse on the same page(Vadim)
Allow installation-configuration option to auto-add all local users(Bryan)
Allow libpq to distinguish between text value " and null(Bruce)
Allow non-postgres users with createdb privs to destroydb's
Allow restriction on who can create C functions(Bryan)
Allow restriction on who can do backend COPY(Bryan)
```

```
Can shrink tables, pg_time and pg_log(Vadim & Erich)
Change debug level 2 to print queries only, changed debug heading layout(Bruce)
Change default decimal constant representation from float4 to float8(Bruce)
European date format now set when postmaster is started
Execute lowercase function names if not found with exact case
Fixes for aggregate/GROUP processing, allow 'select sum(func(x),sum(x+y) from z'
Gist now included in the distribution(Marc)
Idend authentication of local users(Bryan)
Implement BETWEEN qualifier(Bruce)
Implement IN qualifier(Bruce)
libpq has PQgetisnull()(Bruce)
libpq++ improvements
New options to initdb(Bryan)
Pg_dump allow dump of OIDs(Bruce)
Pg_dump create indexes after tables are loaded for speed(Bruce)
Pg_dumpall dumps all databases, and the user table
Pginterface additions for NULL values(Bruce)
Prevent postmaster from being run as root
psql \h and \? is now readable(Bruce)
psql allow backslashed, semicolons anywhere on the line(Bruce)
psql changed command prompt for lines in query or in quotes(Bruce)
psql char(3) now displays as (bp)char in \d output(Bruce)
psql return code now more accurate(Bryan?)
psql updated help syntax(Bruce)
Re-visit and fix vacuum(Vadim)
Reduce size of regression diffs, remove timezone name difference(Bruce)
Remove compile-time parameters to enable binary distributions(Bryan)
Reverse meaning of HBA masks(Bryan)
Secure Authentication of local users(Bryan)
Speed up vacuum(Vadim)
Vacuum now had VERBOSE option(Bruce)

Source tree changes
-------------------
All functions now have prototypes that are compared against the calls
Allow asserts to be disabled easily from Makefile.global(Bruce)
Change oid constants used in code to #define names
Decoupled sparc and solaris defines(Kurt)
Gcc -Wall compiles cleanly with warnings only from unfixable constructs
Major include file reorganization/reduction(Marc)
Make now stops on compile failure(Bryan)
Makefile restructuring(Bryan, Marc)
Merge bsdi_2_1 to bsdi(Bruce)
Monitor program removed
Name change from Postgres95 to PostgreSQL
New config.h file(Marc, Bryan)
PG_VERSION now set to 6.0 and used by postmaster
Portability additions, including Ultrix, DG/UX, AIX, and Solaris
Reduced the number of #define's, centralized #define's
Remove duplicate OIDS in system tables(Dan)
Remove duplicate system catalog info or report mismatches(Dan)
Removed many os-specific #define's
Restructured object file generation/location(Bryan, Marc)
Restructured port-specific file locations(Bryan, Marc)
Unused/uninitialized variables corrected
```

E.264. Release 1.09

Release Date: 1996-11-04

Sorry, we didn't keep track of changes from 1.02 to 1.09. Some of the changes listed in 6.0 were actually included in the 1.02.1 to 1.09 releases.

E.265. Release 1.02

Release Date: 1996-08-01

E.265.1. Migration from version 1.02 to version 1.02.1

Here is a new migration file for 1.02.1. It includes the 'copy' change and a script to convert old ASCII files.

> **Note:** The following notes are for the benefit of users who want to migrate databases from Postgres95 1.01 and 1.02 to Postgres95 1.02.1.
>
> If you are starting afresh with Postgres95 1.02.1 and do not need to migrate old databases, you do not need to read any further.

In order to upgrade older Postgres95 version 1.01 or 1.02 databases to version 1.02.1, the following steps are required:

1. Start up a new 1.02.1 postmaster
2. Add the new built-in functions and operators of 1.02.1 to 1.01 or 1.02 databases. This is done by running the new 1.02.1 server against your own 1.01 or 1.02 database and applying the queries attached at the end of the file. This can be done easily through `psql`. If your 1.01 or 1.02 database is named `testdb` and you have cut the commands from the end of this file and saved them in `addfunc.sql`:

   ```
   % psql testdb -f addfunc.sql
   ```

   Those upgrading 1.02 databases will get a warning when executing the last two statements in the file because they are already present in 1.02. This is not a cause for concern.

E.265.2. Dump/Reload Procedure

If you are trying to reload a pg_dump or text-mode, `copy tablename to stdout` generated with a previous version, you will need to run the attached `sed` script on the ASCII file before loading it into the database. The old format used '.' as end-of-data, while '\.' is now the end-of-data marker. Also, empty strings are now loaded in as '' rather than NULL. See the copy manual page for full details.

```
sed 's/^\.$/\\./g' <in_file >out_file
```

If you are loading an older binary copy or non-stdout copy, there is no end-of-data character, and hence no conversion necessary.

```
-- following lines added by agc to reflect the case-insensitive
-- regexp searching for varchar (in 1.02), and bpchar (in 1.02.1)
create operator ~* (leftarg = bpchar, rightarg = text, procedure = texticregexeq);
create operator !~* (leftarg = bpchar, rightarg = text, procedure = texticregexne);
create operator ~* (leftarg = varchar, rightarg = text, procedure = texticregexeq);
create operator !~* (leftarg = varchar, rightarg = text, procedure = texticregexne);
```

E.265.3. Changes

```
Source code maintenance and development
 * worldwide team of volunteers
 * the source tree now in CVS at ftp.ki.net

Enhancements
 * psql (and underlying libpq library) now has many more options for
   formatting output, including HTML
 * pg_dump now output the schema and/or the data, with many fixes to
   enhance completeness.
 * psql used in place of monitor in administration shell scripts.
   monitor to be deprecated in next release.
 * date/time functions enhanced
 * NULL insert/update/comparison fixed/enhanced
 * TCL/TK lib and shell fixed to work with both tck7.4/tk4.0 and tcl7.5/tk4.1

Bug Fixes (almost too numerous to mention)
 * indexes
 * storage management
 * check for NULL pointer before dereferencing
 * Makefile fixes

New Ports
 * added SolarisX86 port
 * added BSD/OS 2.1 port
 * added DG/UX port
```

E.266. Release 1.01

Release Date: 1996-02-23

E.266.1. Migration from version 1.0 to version 1.01

The following notes are for the benefit of users who want to migrate databases from Postgres95 1.0 to Postgres95 1.01.

If you are starting afresh with Postgres95 1.01 and do not need to migrate old databases, you do not need to read any further.

In order to Postgres95 version 1.01 with databases created with Postgres95 version 1.0, the following steps are required:

1. Set the definition of `NAMEDATALEN` in `src/Makefile.global` to 16 and `OIDNAMELEN` to 20.
2. Decide whether you want to use Host based authentication.

    a. If you do, you must create a file name `pg_hba` in your top-level data directory (typically the value of your `$PGDATA`). `src/libpq/pg_hba` shows an example syntax.

    b. If you do not want host-based authentication, you can comment out the line:

    ```
    HBA = 1
    ```
    in `src/Makefile.global`

    Note that host-based authentication is turned on by default, and if you do not take steps A or B above, the out-of-the-box 1.01 will not allow you to connect to 1.0 databases.
3. Compile and install 1.01, but DO NOT do the `initdb` step.
4. Before doing anything else, terminate your 1.0 postmaster, and backup your existing `$PGDATA` directory.
5. Set your `PGDATA` environment variable to your 1.0 databases, but set up path up so that 1.01 binaries are being used.
6. Modify the file `$PGDATA/PG_VERSION` from 5.0 to 5.1
7. Start up a new 1.01 postmaster
8. Add the new built-in functions and operators of 1.01 to 1.0 databases. This is done by running the new 1.01 server against your own 1.0 database and applying the queries attached and saving in the file 1.0_to_1.01.sql. This can be done easily through `psql`. If your 1.0 database is name `testdb`:

    ```
    % psql testdb -f 1.0_to_1.01.sql
    ```
    and then execute the following commands (cut and paste from here):

    ```
    -- add builtin functions that are new to 1.01

    create function int4eqoid (int4, oid) returns bool as 'foo'
    language 'internal';
    create function oideqint4 (oid, int4) returns bool as 'foo'
    language 'internal';
    create function char2icregexeq (char2, text) returns bool as 'foo'
    language 'internal';
    create function char2icregexne (char2, text) returns bool as 'foo'
    language 'internal';
    create function char4icregexeq (char4, text) returns bool as 'foo'
    language 'internal';
    create function char4icregexne (char4, text) returns bool as 'foo'
    language 'internal';
    create function char8icregexeq (char8, text) returns bool as 'foo'
    language 'internal';
    create function char8icregexne (char8, text) returns bool as 'foo'
    ```

```
   language 'internal';
   create function char16icregexeq (char16, text) returns bool as 'foo'
   language 'internal';
   create function char16icregexne (char16, text) returns bool as 'foo'
   language 'internal';
   create function texticregexeq (text, text) returns bool as 'foo'
   language 'internal';
   create function texticregexne (text, text) returns bool as 'foo'
   language 'internal';

   -- add builtin functions that are new to 1.01

   create operator = (leftarg = int4, rightarg = oid, procedure = int4eqoid);
   create operator = (leftarg = oid, rightarg = int4, procedure = oideqint4);
   create operator ~* (leftarg = char2, rightarg = text, procedure = char2icregexeq);
   create operator !~* (leftarg = char2, rightarg = text, procedure = char2icregexne);
   create operator ~* (leftarg = char4, rightarg = text, procedure = char4icregexeq);
   create operator !~* (leftarg = char4, rightarg = text, procedure = char4icregexne);
   create operator ~* (leftarg = char8, rightarg = text, procedure = char8icregexeq);
   create operator !~* (leftarg = char8, rightarg = text, procedure = char8icregexne);
   create operator ~* (leftarg = char16, rightarg = text, procedure = char16icregexeq);
   create operator !~* (leftarg = char16, rightarg = text, procedure = char16icregexne);
   create operator ~* (leftarg = text, rightarg = text, procedure = texticregexeq);
   create operator !~* (leftarg = text, rightarg = text, procedure = texticregexne);
```

E.266.2. Changes

```
Incompatibilities:
 * 1.01 is backwards compatible with 1.0 database provided the user
   follow the steps outlined in the MIGRATION_from_1.0_to_1.01 file.
   If those steps are not taken, 1.01 is not compatible with 1.0 database.

Enhancements:
 * added PQdisplayTuples() to libpq and changed monitor and psql to use it
 * added NeXT port (requires SysVIPC implementation)
 * added CAST .. AS ... syntax
 * added ASC and DESC key words
 * added 'internal' as a possible language for CREATE FUNCTION
   internal functions are C functions which have been statically linked
   into the postgres backend.
 * a new type "name" has been added for system identifiers (table names,
   attribute names, etc.)  This replaces the old char16 type.   The
   of name is set by the NAMEDATALEN #define in src/Makefile.global
 * a readable reference manual that describes the query language.
 * added host-based access control.  A configuration file ($PGDATA/pg_hba)
   is used to hold the configuration data.  If host-based access control
   is not desired, comment out HBA=1 in src/Makefile.global.
 * changed regex handling to be uniform use of Henry Spencer's regex code
   regardless of platform.  The regex code is included in the distribution
 * added functions and operators for case-insensitive regular expressions.
   The operators are ~* and !~*.
 * pg_dump uses COPY instead of SELECT loop for better performance

Bug fixes:
 * fixed an optimizer bug that was causing core dumps when
```

```
  functions calls were used in comparisons in the WHERE clause
* changed all uses of getuid to geteuid so that effective uids are used
* psql now returns non-zero status on errors when using -c
* applied public patches 1-14
```

E.267. Release 1.0

Release Date: 1995-09-05

E.267.1. Changes

```
Copyright change:
 * The copyright of Postgres 1.0 has been loosened to be freely modifiable
   and modifiable for any purpose.  Please read the COPYRIGHT file.
   Thanks to Professor Michael Stonebraker for making this possible.

Incompatibilities:
 *  date formats have to be MM-DD-YYYY (or DD-MM-YYYY if you're using
   EUROPEAN STYLE).  This follows SQL-92 specs.
 *  "delimiters" is now a key word

Enhancements:
 *  sql LIKE syntax has been added
 *  copy command now takes an optional USING DELIMITER specification.
   delimiters can be any single-character string.
 *  IRIX 5.3 port has been added.
   Thanks to Paul Walmsley and others.
 *  updated pg_dump to work with new libpq
 *  \d has been added psql
   Thanks to Keith Parks
 *  regexp performance for architectures that use POSIX regex has been
   improved due to caching of precompiled patterns.
   Thanks to Alistair Crooks
 *  a new version of libpq++
   Thanks to William Wanders

Bug fixes:
 *  arbitrary userids can be specified in the createuser script
 *  \c to connect to other databases in psql now works.
 *  bad pg_proc entry for float4inc() is fixed
 *  users with usecreatedb field set can now create databases without
   having to be usesuper
 *  remove access control entries when the entry no longer has any
   privileges
 *  fixed non-portable datetimes implementation
 *  added kerberos flags to the src/backend/Makefile
 *  libpq now works with kerberos
 *  typographic errors in the user manual have been corrected.
```

```
 *  btrees with multiple index never worked, now we tell you they don't
   work when you try to use them
```

E.268. Postgres95 Release 0.03

Release Date: 1995-07-21

E.268.1. Changes

```
Incompatible changes:
 * BETA-0.3 IS INCOMPATIBLE WITH DATABASES CREATED WITH PREVIOUS VERSIONS
   (due to system catalog changes and indexing structure changes).
 * double-quote (") is deprecated as a quoting character for string literals;
   you need to convert them to single quotes (').
 * name of aggregates (eg. int4sum) are renamed in accordance with the
   SQL standard (eg. sum).
 * CHANGE ACL syntax is replaced by GRANT/REVOKE syntax.
 * float literals (eg. 3.14) are now of type float4 (instead of float8 in
   previous releases); you might have to do typecasting if you depend on it
   being of type float8.  If you neglect to do the typecasting and you assign
   a float literal to a field of type float8, you might get incorrect values
   stored!
 * LIBPQ has been totally revamped so that frontend applications
   can connect to multiple backends
 * the usesysid field in pg_user has been changed from int2 to int4 to
   allow wider range of Unix user ids.
 * the netbsd/freebsd/bsd o/s ports have been consolidated into a
   single BSD44_derived port.  (thanks to Alistair Crooks)

SQL standard-compliance (the following details changes that makes postgres95
more compliant to the SQL-92 standard):
 * the following SQL types are now built-in: smallint, int(eger), float, real,
   char(N), varchar(N), date and time.

   The following are aliases to existing postgres types:
               smallint -> int2
               integer, int -> int4
               float, real  -> float4
   char(N) and varchar(N) are implemented as truncated text types. In
   addition, char(N) does blank-padding.
 * single-quote (') is used for quoting string literals; '' (in addition to
   \') is supported as means of inserting a single quote in a string
 * SQL standard aggregate names (MAX, MIN, AVG, SUM, COUNT) are used
   (Also, aggregates can now be overloaded, i.e. you can define your
   own MAX aggregate to take in a user-defined type.)
 * CHANGE ACL removed. GRANT/REVOKE syntax added.
   - Privileges can be given to a group using the "GROUP" key word.
        For example:
```

```
                GRANT SELECT ON foobar TO GROUP my_group;
        The key word 'PUBLIC' is also supported to mean all users.

        Privileges can only be granted or revoked to one user or group
        at a time.

        "WITH GRANT OPTION" is not supported.  Only class owners can change
        access control
   - The default access control is to grant users readonly access.
     You must explicitly grant insert/update access to users.  To change
     this, modify the line in
                src/backend/utils/acl.h
     that defines ACL_WORLD_DEFAULT

Bug fixes:
 * the bug where aggregates of empty tables were not run has been fixed. Now,
   aggregates run on empty tables will return the initial conditions of the
   aggregates. Thus, COUNT of an empty  table will now properly return 0.
   MAX/MIN of an empty table will return a row of value NULL.
 * allow the use of \; inside the monitor
 * the LISTEN/NOTIFY asynchronous notification mechanism now work
 * NOTIFY in rule action bodies now work
 * hash indexes work, and access methods in general should perform better.
   creation of large btree indexes should be much faster.  (thanks to Paul
   Aoki)

Other changes and enhancements:
 * addition of an EXPLAIN statement used for explaining the query execution
   plan (eg. "EXPLAIN SELECT * FROM EMP" prints out the execution plan for
   the query).
 * WARN and NOTICE messages no longer have timestamps on them. To turn on
   timestamps of error messages, uncomment the line in
   src/backend/utils/elog.h:
        /* define ELOG_TIMESTAMPS */
 * On an access control violation, the message
        "Either no such class or insufficient privilege"
   will be given.  This is the same message that is returned when
   a class is not found.  This dissuades non-privileged users from
   guessing the existence of privileged classes.
 * some additional system catalog changes have been made that are not
   visible to the user.

libpgtcl changes:
 * The -oid option has been added to the "pg_result" tcl command.
   pg_result -oid returns oid of the last row inserted.   If the
   last command was not an INSERT, then pg_result -oid returns "".
 * the large object interface is available as pg_lo* tcl commands:
   pg_lo_open, pg_lo_close, pg_lo_creat, etc.

Portability enhancements and New Ports:
 * flex/lex problems have been cleared up.  Now, you should be able to use
   flex instead of lex on any platforms.  We no longer make assumptions of
   what lexer you use based on the platform you use.
 * The Linux-ELF port is now supported.  Various configuration have been
   tested:  The following configuration is known to work:
        kernel 1.2.10, gcc 2.6.3, libc 4.7.2, flex 2.5.2, bison 1.24
   with everything in ELF format,
```

```
New utilities:
 * ipcclean added to the distribution
   ipcclean usually does not need to be run, but if your backend crashes
   and leaves shared memory segments hanging around, ipcclean will
   clean them up for you.

New documentation:
 * the user manual has been revised and libpq documentation added.
```

E.269. Postgres95 Release 0.02

Release Date: 1995-05-25

E.269.1. Changes

```
Incompatible changes:
 * The SQL statement for creating a database is 'CREATE DATABASE' instead
   of 'CREATEDB'. Similarly, dropping a database is 'DROP DATABASE' instead
   of 'DESTROYDB'. However, the names of the executables 'createdb' and
   'destroydb' remain the same.

New tools:
 * pgperl - a Perl (4.036) interface to Postgres95
 * pg_dump - a utility for dumping out a postgres database into a
        script file containing query commands. The script files are in an ASCII
        format and can be used to reconstruct the database, even on other
        machines and other architectures. (Also good for converting
        a Postgres 4.2 database to Postgres95 database.)

The following ports have been incorporated into postgres95-beta-0.02:
 * the NetBSD port by Alistair Crooks
 * the AIX port by Mike Tung
 * the Windows NT port by Jon Forrest (more stuff but not done yet)
 * the Linux ELF port by Brian Gallew

The following bugs have been fixed in postgres95-beta-0.02:
 * new lines not escaped in COPY OUT and problem with COPY OUT when first
   attribute is a '.'
 * cannot type return to use the default user id in createuser
 * SELECT DISTINCT on big tables crashes
 * Linux installation problems
 * monitor doesn't allow use of 'localhost' as PGHOST
 * psql core dumps when doing \c or \l
 * the "pgtclsh" target missing from src/bin/pgtclsh/Makefile
 * libpgtcl has a hard-wired default port number
 * SELECT DISTINCT INTO TABLE hangs
 * CREATE TYPE doesn't accept 'variable' as the internallength
```

```
* wrong result using more than 1 aggregate in a SELECT
```

E.270. Postgres95 Release 0.01

Release Date: 1995-05-01

Initial release.

Appendix F. Additional Supplied Modules

This appendix and the next one contain information regarding the modules that can be found in the `contrib` directory of the PostgreSQL distribution. These include porting tools, analysis utilities, and plug-in features that are not part of the core PostgreSQL system, mainly because they address a limited audience or are too experimental to be part of the main source tree. This does not preclude their usefulness.

This appendix covers extensions and other server plug-in modules found in `contrib`. Appendix G covers utility programs.

When building from the source distribution, these components are not built automatically, unless you build the "world" target (see step 2). You can build and install all of them by running:

```
make
make install
```

in the `contrib` directory of a configured source tree; or to build and install just one selected module, do the same in that module's subdirectory. Many of the modules have regression tests, which can be executed by running:

```
make check
```

before installation or

```
make installcheck
```

once you have a PostgreSQL server running.

If you are using a pre-packaged version of PostgreSQL, these modules are typically made available as a separate subpackage, such as `postgresql-contrib`.

Many modules supply new user-defined functions, operators, or types. To make use of one of these modules, after you have installed the code you need to register the new SQL objects in the database system. In PostgreSQL 9.1 and later, this is done by executing a CREATE EXTENSION command. In a fresh database, you can simply do

```
CREATE EXTENSION module_name;
```

This command must be run by a database superuser. This registers the new SQL objects in the current database only, so you need to run this command in each database that you want the module's facilities to be available in. Alternatively, run it in database `template1` so that the extension will be copied into subsequently-created databases by default.

Many modules allow you to install their objects in a schema of your choice. To do that, add `SCHEMA` *`schema_name`* to the `CREATE EXTENSION` command. By default, the objects will be placed in your current creation target schema, typically `public`.

If your database was brought forward by dump and reload from a pre-9.1 version of PostgreSQL, and you had been using the pre-9.1 version of the module in it, you should instead do

```
CREATE EXTENSION module_name FROM unpackaged;
```

This will update the pre-9.1 objects of the module into a proper *extension* object. Future updates to the module will be managed by ALTER EXTENSION. For more information about extension updates, see Section 35.15.

Note, however, that some of these modules are not "extensions" in this sense, but are loaded into the server in some other way, for instance by way of shared_preload_libraries. See the documentation of each module for details.

F.1. adminpack

`adminpack` provides a number of support functions which pgAdmin and other administration and management tools can use to provide additional functionality, such as remote management of server log files.

F.1.1. Functions Implemented

The functions implemented by `adminpack` can only be run by a superuser. Here's a list of these functions:

```
int8 pg_catalog.pg_file_write(fname text, data text, append bool)
bool pg_catalog.pg_file_rename(oldname text, newname text, archivename text)
bool pg_catalog.pg_file_rename(oldname text, newname text)
bool pg_catalog.pg_file_unlink(fname text)
setof record pg_catalog.pg_logdir_ls()

/* Renaming of existing backend functions for pgAdmin compatibility */
int8 pg_catalog.pg_file_read(fname text, data text, append bool)
bigint pg_catalog.pg_file_length(text)
int4 pg_catalog.pg_logfile_rotate()
```

F.2. auth_delay

`auth_delay` causes the server to pause briefly before reporting authentication failure, to make brute-force attacks on database passwords more difficult. Note that it does nothing to prevent denial-of-service attacks, and may even exacerbate them, since processes that are waiting before reporting authentication failure will still consume connection slots.

In order to function, this module must be loaded via shared_preload_libraries in `postgresql.conf`.

F.2.1. Configuration Parameters

`auth_delay.milliseconds` (`int`)

The number of milliseconds to wait before reporting an authentication failure. The default is 0.

These parameters must be set in `postgresql.conf`. Typical usage might be:

```
# postgresql.conf
shared_preload_libraries = 'auth_delay'
```

```
auth_delay.milliseconds = '500'
```

F.2.2. Author

KaiGai Kohei <kaigai@ak.jp.nec.com>

F.3. auto_explain

The auto_explain module provides a means for logging execution plans of slow statements automatically, without having to run EXPLAIN by hand. This is especially helpful for tracking down un-optimized queries in large applications.

The module provides no SQL-accessible functions. To use it, simply load it into the server. You can load it into an individual session:

```
LOAD 'auto_explain';
```

(You must be superuser to do that.) More typical usage is to preload it into some or all sessions by including auto_explain in session_preload_libraries or shared_preload_libraries in postgresql.conf. Then you can track unexpectedly slow queries no matter when they happen. Of course there is a price in overhead for that.

F.3.1. Configuration Parameters

There are several configuration parameters that control the behavior of auto_explain. Note that the default behavior is to do nothing, so you must set at least auto_explain.log_min_duration if you want any results.

auto_explain.log_min_duration (integer)

auto_explain.log_min_duration is the minimum statement execution time, in milliseconds, that will cause the statement's plan to be logged. Setting this to zero logs all plans. Minus-one (the default) disables logging of plans. For example, if you set it to 250ms then all statements that run 250ms or longer will be logged. Only superusers can change this setting.

auto_explain.log_analyze (boolean)

auto_explain.log_analyze causes EXPLAIN ANALYZE output, rather than just EXPLAIN output, to be printed when an execution plan is logged. This parameter is off by default. Only superusers can change this setting.

> **Note:** When this parameter is on, per-plan-node timing occurs for all statements executed, whether or not they run long enough to actually get logged. This can have an extremely negative impact on performance. Turning off auto_explain.log_timing ameliorates the performance cost, at the price of obtaining less information.

`auto_explain.log_buffers` (`boolean`)

`auto_explain.log_buffers` controls whether buffer usage statistics are printed when an execution plan is logged; it's equivalent to the `BUFFERS` option of `EXPLAIN`. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_timing` (`boolean`)

`auto_explain.log_timing` controls whether per-node timing information is printed when an execution plan is logged; it's equivalent to the `TIMING` option of `EXPLAIN`. The overhead of repeatedly reading the system clock can slow down queries significantly on some systems, so it may be useful to set this parameter to off when only actual row counts, and not exact times, are needed. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is on by default. Only superusers can change this setting.

`auto_explain.log_triggers` (`boolean`)

`auto_explain.log_triggers` causes trigger execution statistics to be included when an execution plan is logged. This parameter has no effect unless `auto_explain.log_analyze` is enabled. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_verbose` (`boolean`)

`auto_explain.log_verbose` controls whether verbose details are printed when an execution plan is logged; it's equivalent to the `VERBOSE` option of `EXPLAIN`. This parameter is off by default. Only superusers can change this setting.

`auto_explain.log_format` (`enum`)

`auto_explain.log_format` selects the `EXPLAIN` output format to be used. The allowed values are `text`, `xml`, `json`, and `yaml`. The default is text. Only superusers can change this setting.

`auto_explain.log_nested_statements` (`boolean`)

`auto_explain.log_nested_statements` causes nested statements (statements executed inside a function) to be considered for logging. When it is off, only top-level query plans are logged. This parameter is off by default. Only superusers can change this setting.

In ordinary usage, these parameters are set in `postgresql.conf`, although superusers can alter them on-the-fly within their own sessions. Typical usage might be:

```
# postgresql.conf
session_preload_libraries = 'auto_explain'

auto_explain.log_min_duration = '3s'
```

F.3.2. Example

```
postgres=# LOAD 'auto_explain';
postgres=# SET auto_explain.log_min_duration = 0;
postgres=# SET auto_explain.log_analyze = true;
postgres=# SELECT count(*)
           FROM pg_class, pg_index
           WHERE oid = indrelid AND indisunique;
```

This might produce log output such as:

```
LOG:  duration: 3.651 ms  plan:
```

```
Query Text: SELECT count(*)
            FROM pg_class, pg_index
            WHERE oid = indrelid AND indisunique;
Aggregate  (cost=16.79..16.80 rows=1 width=0) (actual time=3.626..3.627 rows=1 loops=1
  ->  Hash Join  (cost=4.17..16.55 rows=92 width=0) (actual time=3.349..3.594 rows=92
        Hash Cond: (pg_class.oid = pg_index.indrelid)
        ->  Seq Scan on pg_class  (cost=0.00..9.55 rows=255 width=4) (actual time=0.01
        ->  Hash  (cost=3.02..3.02 rows=92 width=4) (actual time=3.238..3.238 rows=92
              Buckets: 1024  Batches: 1  Memory Usage: 4kB
              ->  Seq Scan on pg_index  (cost=0.00..3.02 rows=92 width=4) (actual time
                    Filter: indisunique
```

F.3.3. Author

Takahiro Itagaki <itagaki.takahiro@oss.ntt.co.jp>

F.4. btree_gin

btree_gin provides sample GIN operator classes that implement B-tree equivalent behavior for the data types int2, int4, int8, float4, float8, timestamp with time zone, timestamp without time zone, time with time zone, time without time zone, date, interval, oid, money, "char", varchar, text, bytea, bit, varbit, macaddr, inet, and cidr.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they are useful for GIN testing and as a base for developing other GIN operator classes. Also, for queries that test both a GIN-indexable column and a B-tree-indexable column, it might be more efficient to create a multicolumn GIN index that uses one of these operator classes than to create two separate indexes that would have to be combined via bitmap ANDing.

F.4.1. Example Usage

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING gin (a);
-- query
SELECT * FROM test WHERE a < 10;
```

F.4.2. Authors

Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See http://www.sai.msu.su/~megera/oddmuse/index.cgi/Gin for additional information.

F.5. btree_gist

btree_gist provides GiST index operator classes that implement B-tree equivalent behavior for the data types int2, int4, int8, float4, float8, numeric, timestamp with time zone, timestamp without time zone, time with time zone, time without time zone, date, interval, oid, money, char, varchar, text, bytea, bit, varbit, macaddr, inet, and cidr.

In general, these operator classes will not outperform the equivalent standard B-tree index methods, and they lack one major feature of the standard B-tree code: the ability to enforce uniqueness. However, they provide some other features that are not available with a B-tree index, as described below. Also, these operator classes are useful when a multicolumn GiST index is needed, wherein some of the columns are of data types that are only indexable with GiST but other columns are just simple data types. Lastly, these operator classes are useful for GiST testing and as a base for developing other GiST operator classes.

In addition to the typical B-tree search operators, btree_gist also provides index support for <> ("not equals"). This may be useful in combination with an exclusion constraint, as described below.

Also, for data types for which there is a natural distance metric, btree_gist defines a distance operator <->, and provides GiST index support for nearest-neighbor searches using this operator. Distance operators are provided for int2, int4, int8, float4, float8, timestamp with time zone, timestamp without time zone, time without time zone, date, interval, oid, and money.

F.5.1. Example Usage

Simple example using btree_gist instead of btree:

```
CREATE TABLE test (a int4);
-- create index
CREATE INDEX testidx ON test USING gist (a);
-- query
SELECT * FROM test WHERE a < 10;
-- nearest-neighbor search: find the ten entries closest to "42"
SELECT *, a <-> 42 AS dist FROM test ORDER BY a <-> 42 LIMIT 10;
```

Use an exclusion constraint to enforce the rule that a cage at a zoo can contain only one kind of animal:

```
=> CREATE TABLE zoo (
  cage   INTEGER,
  animal TEXT,
  EXCLUDE USING gist (cage WITH =, animal WITH <>)
);

=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'zebra');
INSERT 0 1
=> INSERT INTO zoo VALUES(123, 'lion');
ERROR:  conflicting key value violates exclusion constraint "zoo_cage_animal_excl"
DETAIL:  Key (cage, animal)=(123, lion) conflicts with existing key (cage, animal)=(123,
=> INSERT INTO zoo VALUES(124, 'lion');
INSERT 0 1
```

F.5.2. Authors

Teodor Sigaev (<teodor@stack.net>) , Oleg Bartunov (<oleg@sai.msu.su>), and Janko Richter (<jankorichter@yahoo.de>). See http://www.sai.msu.su/~megera/postgres/gist/ for additional information.

F.6. chkpass

This module implements a data type `chkpass` that is designed for storing encrypted passwords. Each password is automatically converted to encrypted form upon entry, and is always stored encrypted. To compare, simply compare against a clear text password and the comparison function will encrypt it before comparing.

There are provisions in the code to report an error if the password is determined to be easily crackable. However, this is currently just a stub that does nothing.

If you precede an input string with a colon, it is assumed to be an already-encrypted password, and is stored without further encryption. This allows entry of previously-encrypted passwords.

On output, a colon is prepended. This makes it possible to dump and reload passwords without re-encrypting them. If you want the encrypted password without the colon then use the `raw()` function. This allows you to use the type with things like Apache's `Auth_PostgreSQL` module.

The encryption uses the standard Unix function `crypt()`, and so it suffers from all the usual limitations of that function; notably that only the first eight characters of a password are considered.

Note that the `chkpass` data type is not indexable.

Sample usage:

```
test=# create table test (p chkpass);
CREATE TABLE
test=# insert into test values ('hello');
INSERT 0 1
test=# select * from test;
       p
----------------
 :dVGkpXdOrE3ko
(1 row)

test=# select raw(p) from test;
      raw
---------------
 dVGkpXdOrE3ko
(1 row)

test=# select p = 'hello' from test;
 ?column?
----------
 t
(1 row)

test=# select p = 'goodbye' from test;
 ?column?
----------
 f
```

```
(1 row)
```

F.6.1. Author

D'Arcy J.M. Cain (<darcy@druid.net>)

F.7. citext

The citext module provides a case-insensitive character string type, citext. Essentially, it internally calls lower when comparing values. Otherwise, it behaves almost exactly like text.

F.7.1. Rationale

The standard approach to doing case-insensitive matches in PostgreSQL has been to use the lower function when comparing values, for example

```
SELECT * FROM tab WHERE lower(col) = LOWER(?);
```

This works reasonably well, but has a number of drawbacks:

- It makes your SQL statements verbose, and you always have to remember to use lower on both the column and the query value.
- It won't use an index, unless you create a functional index using lower.
- If you declare a column as UNIQUE or PRIMARY KEY, the implicitly generated index is case-sensitive. So it's useless for case-insensitive searches, and it won't enforce uniqueness case-insensitively.

The citext data type allows you to eliminate calls to lower in SQL queries, and allows a primary key to be case-insensitive. citext is locale-aware, just like text, which means that the matching of upper case and lower case characters is dependent on the rules of the database's LC_CTYPE setting. Again, this behavior is identical to the use of lower in queries. But because it's done transparently by the data type, you don't have to remember to do anything special in your queries.

F.7.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE users (
    nick CITEXT PRIMARY KEY,
    pass TEXT   NOT NULL
);

INSERT INTO users VALUES ( 'larry',  md5(random()::text) );
INSERT INTO users VALUES ( 'Tom',    md5(random()::text) );
INSERT INTO users VALUES ( 'Damian', md5(random()::text) );
INSERT INTO users VALUES ( 'NEAL',   md5(random()::text) );
INSERT INTO users VALUES ( 'Bjørn',  md5(random()::text) );
```

```
SELECT * FROM users WHERE nick = 'Larry';
```

The SELECT statement will return one tuple, even though the nick column was set to larry and the query was for Larry.

F.7.3. String Comparison Behavior

citext performs comparisons by converting each string to lower case (as though lower were called) and then comparing the results normally. Thus, for example, two strings are considered equal if lower would produce identical results for them.

In order to emulate a case-insensitive collation as closely as possible, there are citext-specific versions of a number of string-processing operators and functions. So, for example, the regular expression operators ~ and ~* exhibit the same behavior when applied to citext: they both match case-insensitively. The same is true for !~ and !~*, as well as for the LIKE operators ~~ and ~~*, and !~~ and !~~*. If you'd like to match case-sensitively, you can cast the operator's arguments to text.

Similarly, all of the following functions perform matching case-insensitively if their arguments are citext:

- regexp_replace()
- regexp_split_to_array()
- regexp_split_to_table()
- replace()
- split_part()
- strpos()
- translate()

For the regexp functions, if you want to match case-sensitively, you can specify the "c" flag to force a case-sensitive match. Otherwise, you must cast to text before using one of these functions if you want case-sensitive behavior.

F.7.4. Limitations

- citext's case-folding behavior depends on the LC_CTYPE setting of your database. How it compares values is therefore determined when the database is created. It is not truly case-insensitive in the terms defined by the Unicode standard. Effectively, what this means is that, as long as you're happy with your collation, you should be happy with citext's comparisons. But if you have data in different languages stored in your database, users of one language may find their query results are not as expected if the collation is for another language.
- As of PostgreSQL 9.1, you can attach a COLLATE specification to citext columns or data values. Currently, citext operators will honor a non-default COLLATE specification while comparing case-folded strings, but the initial folding to lower case is always done according to the database's LC_CTYPE setting (that is, as though COLLATE "default" were given). This may be changed in a future release so that both steps follow the input COLLATE specification.

- `citext` is not as efficient as `text` because the operator functions and the B-tree comparison functions must make copies of the data and convert it to lower case for comparisons. It is, however, slightly more efficient than using `lower` to get case-insensitive matching.
- `citext` doesn't help much if you need data to compare case-sensitively in some contexts and case-insensitively in other contexts. The standard answer is to use the `text` type and manually use the `lower` function when you need to compare case-insensitively; this works all right if case-insensitive comparison is needed only infrequently. If you need case-insensitive behavior most of the time and case-sensitive infrequently, consider storing the data as `citext` and explicitly casting the column to `text` when you want case-sensitive comparison. In either situation, you will need two indexes if you want both types of searches to be fast.
- The schema containing the `citext` operators must be in the current `search_path` (typically `public`); if it is not, the normal case-sensitive `text` operators will be invoked instead.

F.7.5. Author

David E. Wheeler <`david@kineticode.com`>

Inspired by the original `citext` module by Donald Fraser.

F.8. cube

This module implements a data type `cube` for representing multidimensional cubes.

F.8.1. Syntax

Table F-1 shows the valid external representations for the `cube` type. *x*, *y*, etc. denote floating-point numbers.

Table F-1. Cube External Representations

x	A one-dimensional point (or, zero-length one-dimensional interval)
(*x*)	Same as above
x1,*x2*,...,*xn*	A point in n-dimensional space, represented internally as a zero-volume cube
(*x1*,*x2*,...,*xn*)	Same as above
(*x*),(*y*)	A one-dimensional interval starting at *x* and ending at *y* or vice versa; the order does not matter
[(*x*),(*y*)]	Same as above
(*x1*,...,*xn*),(*y1*,...,*yn*)	An n-dimensional cube represented by a pair of its diagonally opposite corners
[(*x1*,...,*xn*),(*y1*,...,*yn*)]	Same as above

It does not matter which order the opposite corners of a cube are entered in. The `cube` functions automatically swap values if needed to create a uniform "lower left — upper right" internal representation.

White space is ignored, so `[(x),(y)]` is the same as `[ ( x ), ( y ) ]`.

F.8.2. Precision

Values are stored internally as 64-bit floating point numbers. This means that numbers with more than about 16 significant digits will be truncated.

F.8.3. Usage

The `cube` module includes a GiST index operator class for `cube` values. The operators supported by the GiST operator class are shown in Table F-2.

Table F-2. Cube GiST Operators

Operator	Description
`a = b`	The cubes a and b are identical.
`a && b`	The cubes a and b overlap.
`a @> b`	The cube a contains the cube b.
`a <@ b`	The cube a is contained in the cube b.

(Before PostgreSQL 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The standard B-tree operators are also provided, for example

Operator	Description
`[a, b] < [c, d]`	Less than
`[a, b] > [c, d]`	Greater than

These operators do not make a lot of sense for any practical purpose but sorting. These operators first compare (a) to (c), and if these are equal, compare (b) to (d). That results in reasonably good sorting in most cases, which is useful if you want to use ORDER BY with this type.

Table F-3 shows the available functions.

Table F-3. Cube Functions

`cube(float8) returns cube`	Makes a one dimensional cube with both coordinates the same. `cube(1) == '(1)'`
`cube(float8, float8) returns cube`	Makes a one dimensional cube. `cube(1,2) == '(1),(2)'`
`cube(float8[]) returns cube`	Makes a zero-volume cube using the coordinates defined by the array. `cube(ARRAY[1,2]) == '(1,2)'`

`cube(float8[], float8[]) returns cube`	Makes a cube with upper right and lower left coordinates as defined by the two arrays, which must be of the same length. `cube('{1,2}'::float[], '{3,4}'::float[]) == '(1,2),(3,4)'`
`cube(cube, float8) returns cube`	Makes a new cube by adding a dimension on to an existing cube with the same values for both parts of the new coordinate. This is useful for building cubes piece by piece from calculated values. `cube('(1)',2) == '(1,2),(1,2)'`
`cube(cube, float8, float8) returns cube`	Makes a new cube by adding a dimension on to an existing cube. This is useful for building cubes piece by piece from calculated values. `cube('(1,2)',3,4) == '(1,3),(2,4)'`
`cube_dim(cube) returns int`	Returns the number of dimensions of the cube
`cube_ll_coord(cube, int) returns double`	Returns the n'th coordinate value for the lower left corner of a cube
`cube_ur_coord(cube, int) returns double`	Returns the n'th coordinate value for the upper right corner of a cube
`cube_is_point(cube) returns bool`	Returns true if a cube is a point, that is, the two defining corners are the same.
`cube_distance(cube, cube) returns double`	Returns the distance between two cubes. If both cubes are points, this is the normal distance function.
`cube_subset(cube, int[]) returns cube`	Makes a new cube from an existing cube, using a list of dimension indexes from an array. Can be used to find both the LL and UR coordinates of a single dimension, e.g. `cube_subset(cube('(1,3,5),(6,7,8)'), ARRAY[2]) = '(3),(7)'`. Or can be used to drop dimensions, or reorder them as desired, e.g. `cube_subset(cube('(1,3,5),(6,7,8)'), ARRAY[3,2,1,1]) = '(5, 3, 1, 1),(8, 7, 6, 6)'`.
`cube_union(cube, cube) returns cube`	Produces the union of two cubes
`cube_inter(cube, cube) returns cube`	Produces the intersection of two cubes

`cube_enlarge(cube c, double r, int n) returns cube`	Increases the size of a cube by a specified radius in at least n dimensions. If the radius is negative the cube is shrunk instead. This is useful for creating bounding boxes around a point for searching for nearby points. All defined dimensions are changed by the radius r. LL coordinates are decreased by r and UR coordinates are increased by r. If a LL coordinate is increased to larger than the corresponding UR coordinate (this can only happen when r $<$ 0) than both coordinates are set to their average. If n is greater than the number of defined dimensions and the cube is being increased (r $>=$ 0) then 0 is used as the base for the extra coordinates.

F.8.4. Defaults

I believe this union:

```
select cube_union('(0,5,2),(2,3,1)', '0');
cube_union
-------------------
(0, 0, 0),(2, 5, 2)
(1 row)
```

does not contradict common sense, neither does the intersection

```
select cube_inter('(0,-1),(1,1)', '(-2),(2)');
cube_inter
-------------
(0, 0),(1, 0)
(1 row)
```

In all binary operations on differently-dimensioned cubes, I assume the lower-dimensional one to be a Cartesian projection, i. e., having zeroes in place of coordinates omitted in the string representation. The above examples are equivalent to:

```
cube_union('(0,5,2),(2,3,1)','(0,0,0),(0,0,0)');
cube_inter('(0,-1),(1,1)','(-2,0),(2,0)');
```

The following containment predicate uses the point syntax, while in fact the second argument is internally represented by a box. This syntax makes it unnecessary to define a separate point type and functions for (box,point) predicates.

```
select cube_contains('(0,0),(1,1)', '0.5,0.5');
cube_contains
--------------
t
(1 row)
```

F.8.5. Notes

For examples of usage, see the regression test `sql/cube.sql`.

To make it harder for people to break things, there is a limit of 100 on the number of dimensions of cubes. This is set in `cubedata.h` if you need something bigger.

F.8.6. Credits

Original author: Gene Selkov, Jr. <`selkovjr@mcs.anl.gov`>, Mathematics and Computer Science Division, Argonne National Laboratory.

My thanks are primarily to Prof. Joe Hellerstein (http://db.cs.berkeley.edu/jmh/) for elucidating the gist of the GiST (http://gist.cs.berkeley.edu/), and to his former student, Andy Dong (http://best.me.berkeley.edu/~adong/), for his example written for Illustra, http://best.berkeley.edu/~adong/rtree/index.html. I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

Minor updates to this package were made by Bruno Wolff III <`bruno@wolff.to`> in August/September of 2002. These include changing the precision from single precision to double precision and adding some new functions.

Additional updates were made by Joshua Reich <`josh@root.net`> in July 2006. These include `cube(float8[], float8[])` and cleaning up the code to use the V1 call protocol instead of the deprecated V0 protocol.

F.9. dblink

`dblink` is a module that supports connections to other PostgreSQL databases from within a database session.

See also postgres_fdw, which provides roughly the same functionality using a more modern and standards-compliant infrastructure.

dblink_connect

Name

`dblink_connect` — opens a persistent connection to a remote database

Synopsis

```
dblink_connect(text connstr) returns text
dblink_connect(text connname, text connstr) returns text
```

Description

`dblink_connect()` establishes a connection to a remote PostgreSQL database. The server and database to be contacted are identified through a standard libpq connection string. Optionally, a name can be assigned to the connection. Multiple named connections can be open at once, but only one unnamed connection is permitted at a time. The connection will persist until closed or until the database session is ended.

The connection string may also be the name of an existing foreign server. It is recommended to use the foreign-data wrapper `dblink_fdw` when defining the foreign server. See the example below, as well as CREATE SERVER and CREATE USER MAPPING.

Arguments

`conname`

The name to use for this connection; if omitted, an unnamed connection is opened, replacing any existing unnamed connection.

`connstr`

libpq-style connection info string, for example `hostaddr=127.0.0.1 port=5432 dbname=mydb user=postgres password=mypasswd`. For details see Section 31.1.1. Alternatively, the name of a foreign server.

Return Value

Returns status, which is always `OK` (since any error causes the function to throw an error instead of returning).

Notes

Only superusers may use `dblink_connect` to create non-password-authenticated connections. If non-superusers need this capability, use `dblink_connect_u` instead.

It is unwise to choose connection names that contain equal signs, as this opens a risk of confusion with connection info strings in other `dblink` functions.

Examples

```
SELECT dblink_connect('dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)

SELECT dblink_connect('myconn', 'dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)
```

```
-- FOREIGN DATA WRAPPER functionality
-- Note: local connection must require password authentication for this to work properly
--       Otherwise, you will receive the following error from dblink_connect():
--       ------------------------------------------------------------------------
--       ERROR:  password is required
--       DETAIL:  Non-superuser cannot connect if the server does not request a password
--       HINT:  Target server's authentication method must be changed.

CREATE SERVER fdtest FOREIGN DATA WRAPPER dblink_fdw OPTIONS (hostaddr '127.0.0.1', dbna

CREATE USER dblink_regression_test WITH PASSWORD 'secret';
CREATE USER MAPPING FOR dblink_regression_test SERVER fdtest OPTIONS (user 'dblink_regre
GRANT USAGE ON FOREIGN SERVER fdtest TO dblink_regression_test;
GRANT SELECT ON TABLE foo TO dblink_regression_test;

\set ORIGINAL_USER :USER
\c - dblink_regression_test
SELECT dblink_connect('myconn', 'fdtest');
 dblink_connect
----------------
 OK
(1 row)

SELECT * FROM dblink('myconn','SELECT * FROM foo') AS t(a int, b text, c text[]);
 a  | b |       c
----+---+---------------
  0 | a | {a0,b0,c0}
  1 | b | {a1,b1,c1}
  2 | c | {a2,b2,c2}
  3 | d | {a3,b3,c3}
  4 | e | {a4,b4,c4}
  5 | f | {a5,b5,c5}
  6 | g | {a6,b6,c6}
  7 | h | {a7,b7,c7}
  8 | i | {a8,b8,c8}
  9 | j | {a9,b9,c9}
 10 | k | {a10,b10,c10}
(11 rows)

\c - :ORIGINAL_USER
REVOKE USAGE ON FOREIGN SERVER fdtest FROM dblink_regression_test;
REVOKE SELECT ON TABLE foo FROM dblink_regression_test;
DROP USER MAPPING FOR dblink_regression_test SERVER fdtest;
DROP USER dblink_regression_test;
DROP SERVER fdtest;
```

dblink_connect_u

Name

dblink_connect_u — opens a persistent connection to a remote database, insecurely

Synopsis

```
dblink_connect_u(text connstr) returns text
dblink_connect_u(text connname, text connstr) returns text
```

Description

dblink_connect_u() is identical to dblink_connect(), except that it will allow non-superusers to connect using any authentication method.

If the remote server selects an authentication method that does not involve a password, then impersonation and subsequent escalation of privileges can occur, because the session will appear to have originated from the user as which the local PostgreSQL server runs. Also, even if the remote server does demand a password, it is possible for the password to be supplied from the server environment, such as a ~/.pgpass file belonging to the server's user. This opens not only a risk of impersonation, but the possibility of exposing a password to an untrustworthy remote server. Therefore, dblink_connect_u() is initially installed with all privileges revoked from PUBLIC, making it un-callable except by superusers. In some situations it may be appropriate to grant EXECUTE permission for dblink_connect_u() to specific users who are considered trustworthy, but this should be done with care. It is also recommended that any ~/.pgpass file belonging to the server's user *not* contain any records specifying a wildcard host name.

For further details see dblink_connect().

dblink_disconnect

Name

`dblink_disconnect` — closes a persistent connection to a remote database

Synopsis

```
dblink_disconnect() returns text
dblink_disconnect(text connname) returns text
```

Description

`dblink_disconnect()` closes a connection previously opened by `dblink_connect()`. The form with no arguments closes an unnamed connection.

Arguments

`conname`

The name of a named connection to be closed.

Return Value

Returns status, which is always `OK` (since any error causes the function to throw an error instead of returning).

Examples

```
SELECT dblink_disconnect();
 dblink_disconnect
-------------------
 OK
(1 row)

SELECT dblink_disconnect('myconn');
 dblink_disconnect
-------------------
 OK
(1 row)
```

dblink

Name

dblink — executes a query in a remote database

Synopsis

```
dblink(text connname, text sql [, bool fail_on_error]) returns setof record
dblink(text connstr, text sql [, bool fail_on_error]) returns setof record
dblink(text sql [, bool fail_on_error]) returns setof record
```

Description

dblink executes a query (usually a SELECT, but it can be any SQL statement that returns rows) in a remote database.

When two text arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for dblink_connect, and the indicated connection is made just for the duration of this command.

Arguments

conname

Name of the connection to use; omit this parameter to use the unnamed connection.

connstr

A connection info string, as previously described for dblink_connect.

sql

The SQL query that you wish to execute in the remote database, for example select * from foo.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

Return Value

The function returns the row(s) produced by the query. Since dblink can be used with any query, it is declared to return record, rather than specifying any particular set of columns. This means that you must specify the expected set of columns in the calling query — otherwise PostgreSQL would not know what to expect. Here is an example:

```
SELECT *
    FROM dblink('dbname=mydb', 'select proname, prosrc from pg_proc')
```

```
      AS t1(proname name, prosrc text)
    WHERE proname LIKE 'bytea%';
```

The "alias" part of the `FROM` clause must specify the column names and types that the function will return. (Specifying column names in an alias is actually standard SQL syntax, but specifying column types is a PostgreSQL extension.) This allows the system to understand what `*` should expand to, and what `proname` in the `WHERE` clause refers to, in advance of trying to execute the function. At run time, an error will be thrown if the actual query result from the remote database does not have the same number of columns shown in the `FROM` clause. The column names need not match, however, and `dblink` does not insist on exact type matches either. It will succeed so long as the returned data strings are valid input for the column type declared in the `FROM` clause.

Notes

A convenient way to use `dblink` with predetermined queries is to create a view. This allows the column type information to be buried in the view, instead of having to spell it out in every query. For example,

```
CREATE VIEW myremote_pg_proc AS
  SELECT *
    FROM dblink('dbname=postgres', 'select proname, prosrc from pg_proc')
    AS t1(proname name, prosrc text);

SELECT * FROM myremote_pg_proc WHERE proname LIKE 'bytea%';
```

Examples

```
SELECT * FROM dblink('dbname=postgres', 'select proname, prosrc from pg_proc')
  AS t1(proname name, prosrc text) WHERE proname LIKE 'bytea%';
  proname   |   prosrc
------------+------------
 byteacat   | byteacat
 byteaeq    | byteaeq
 bytealt    | bytealt
 byteale    | byteale
 byteagt    | byteagt
 byteage    | byteage
 byteane    | byteane
 byteacmp   | byteacmp
 bytealike  | bytealike
 byteanlike | byteanlike
 byteain    | byteain
 byteaout   | byteaout
(12 rows)

SELECT dblink_connect('dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)
```

```
SELECT * FROM dblink('select proname, prosrc from pg_proc')
  AS t1(proname name, prosrc text) WHERE proname LIKE 'bytea%';
  proname   |   prosrc
------------+------------
 byteacat   | byteacat
 byteaeq    | byteaeq
 bytealt    | bytealt
 byteale    | byteale
 byteagt    | byteagt
 byteage    | byteage
 byteane    | byteane
 byteacmp   | byteacmp
 bytealike  | bytealike
 byteanlike | byteanlike
 byteain    | byteain
 byteaout   | byteaout
(12 rows)

SELECT dblink_connect('myconn', 'dbname=regression');
 dblink_connect
----------------
 OK
(1 row)

SELECT * FROM dblink('myconn', 'select proname, prosrc from pg_proc')
  AS t1(proname name, prosrc text) WHERE proname LIKE 'bytea%';
  proname   |   prosrc
------------+------------
 bytearecv  | bytearecv
 byteasend  | byteasend
 byteale    | byteale
 byteagt    | byteagt
 byteage    | byteage
 byteane    | byteane
 byteacmp   | byteacmp
 bytealike  | bytealike
 byteanlike | byteanlike
 byteacat   | byteacat
 byteaeq    | byteaeq
 bytealt    | bytealt
 byteain    | byteain
 byteaout   | byteaout
(14 rows)
```

dblink_exec

Name

dblink_exec — executes a command in a remote database

Synopsis

```
dblink_exec(text connname, text sql [, bool fail_on_error]) returns text
dblink_exec(text connstr, text sql [, bool fail_on_error]) returns text
dblink_exec(text sql [, bool fail_on_error]) returns text
```

Description

dblink_exec executes a command (that is, any SQL statement that doesn't return rows) in a remote database.

When two text arguments are given, the first one is first looked up as a persistent connection's name; if found, the command is executed on that connection. If not found, the first argument is treated as a connection info string as for dblink_connect, and the indicated connection is made just for the duration of this command.

Arguments

conname

Name of the connection to use; omit this parameter to use the unnamed connection.

connstr

A connection info string, as previously described for dblink_connect.

sql

The SQL command that you wish to execute in the remote database, for example insert into foo values(0,'a','{"a0","b0","c0"}').

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to ERROR.

Return Value

Returns status, either the command's status string or ERROR.

Examples

```
SELECT dblink_connect('dbname=dblink_test_standby');
```

```
 dblink_connect
----------------
 OK
(1 row)

SELECT dblink_exec('insert into foo values(21,"z","{"a0","b0","c0"}");');
   dblink_exec
-----------------
 INSERT 943366 1
(1 row)

SELECT dblink_connect('myconn', 'dbname=regression');
 dblink_connect
----------------
 OK
(1 row)

SELECT dblink_exec('myconn', 'insert into foo values(21,"z","{"a0","b0","c0"}");');
   dblink_exec
------------------
 INSERT 6432584 1
(1 row)

SELECT dblink_exec('myconn', 'insert into pg_class values ("foo")',false);
NOTICE:  sql error
DETAIL:  ERROR:  null value in column "relnamespace" violates not-null constraint

 dblink_exec
-------------
 ERROR
(1 row)
```

dblink_open

Name

dblink_open — opens a cursor in a remote database

Synopsis

```
dblink_open(text cursorname, text sql [, bool fail_on_error]) returns text
dblink_open(text connname, text cursorname, text sql [, bool fail_on_error]) returns tex
```

Description

dblink_open() opens a cursor in a remote database. The cursor can subsequently be manipulated with dblink_fetch() and dblink_close().

Arguments

conname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name to assign to this cursor.

sql

The SELECT statement that you wish to execute in the remote database, for example select * from pg_class.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to ERROR.

Return Value

Returns status, either OK or ERROR.

Notes

Since a cursor can only persist within a transaction, dblink_open starts an explicit transaction block (BEGIN) on the remote side, if the remote side was not already within a transaction. This transaction will be closed again when the matching dblink_close is executed. Note that if you use dblink_exec to change data between dblink_open and dblink_close, and then an error occurs or you use dblink_disconnect before dblink_close, your change *will be lost* because the transaction will be aborted.

Examples

```
SELECT dblink_connect('dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)

SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');
 dblink_open
-------------
 OK
(1 row)
```

dblink_fetch

Name

dblink_fetch — returns rows from an open cursor in a remote database

Synopsis

```
dblink_fetch(text cursorname, int howmany [, bool fail_on_error]) returns setof record
dblink_fetch(text connname, text cursorname, int howmany [, bool fail_on_error]) returns
```

Description

dblink_fetch fetches rows from a cursor previously established by dblink_open.

Arguments

conname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name of the cursor to fetch from.

howmany

The maximum number of rows to retrieve. The next howmany rows are fetched, starting at the current cursor position, moving forward. Once the cursor has reached its end, no more rows are produced.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

Return Value

The function returns the row(s) fetched from the cursor. To use this function, you will need to specify the expected set of columns, as previously discussed for dblink.

Notes

On a mismatch between the number of return columns specified in the FROM clause, and the actual number of columns returned by the remote cursor, an error will be thrown. In this event, the remote cursor is still advanced by as many rows as it would have been if the error had not occurred. The same is true for any other error occurring in the local query after the remote FETCH has been done.

Examples

```
SELECT dblink_connect('dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)

SELECT dblink_open('foo', 'select proname, prosrc from pg_proc where proname like "bytea
 dblink_open
-------------
 OK
(1 row)

SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source text);
 funcname |  source
----------+----------
 byteacat | byteacat
 byteacmp | byteacmp
 byteaeq  | byteaeq
 byteage  | byteage
 byteagt  | byteagt
(5 rows)

SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source text);
 funcname  |  source
-----------+-----------
 byteain   | byteain
 byteale   | byteale
 bytealike | bytealike
 bytealt   | bytealt
 byteane   | byteane
(5 rows)

SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source text);
  funcname  |   source
------------+------------
 byteanlike | byteanlike
 byteaout   | byteaout
(2 rows)

SELECT * FROM dblink_fetch('foo', 5) AS (funcname name, source text);
 funcname | source
----------+--------
(0 rows)
```

dblink_close

Name

dblink_close — closes a cursor in a remote database

Synopsis

```
dblink_close(text cursorname [, bool fail_on_error]) returns text
dblink_close(text connname, text cursorname [, bool fail_on_error]) returns text
```

Description

dblink_close closes a cursor previously opened with dblink_open.

Arguments

conname

Name of the connection to use; omit this parameter to use the unnamed connection.

cursorname

The name of the cursor to close.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function's return value is set to ERROR.

Return Value

Returns status, either OK or ERROR.

Notes

If dblink_open started an explicit transaction block, and this is the last remaining open cursor in this connection, dblink_close will issue the matching COMMIT.

Examples

```
SELECT dblink_connect('dbname=postgres');
 dblink_connect
----------------
 OK
(1 row)
```

```
SELECT dblink_open('foo', 'select proname, prosrc from pg_proc');
 dblink_open
-------------
 OK
(1 row)

SELECT dblink_close('foo');
 dblink_close
--------------
 OK
(1 row)
```

dblink_get_connections

Name

`dblink_get_connections` — returns the names of all open named dblink connections

Synopsis

```
dblink_get_connections() returns text[]
```

Description

`dblink_get_connections` returns an array of the names of all open named `dblink` connections.

Return Value

Returns a text array of connection names, or NULL if none.

Examples

```
SELECT dblink_get_connections();
```

dblink_error_message

Name

`dblink_error_message` — gets last error message on the named connection

Synopsis

```
dblink_error_message(text connname) returns text
```

Description

`dblink_error_message` fetches the most recent remote error message for a given connection.

Arguments

`conname`

Name of the connection to use.

Return Value

Returns last error message, or an empty string if there has been no error in this connection.

Examples

```
SELECT dblink_error_message('dtest1');
```

dblink_send_query

Name

`dblink_send_query` — sends an async query to a remote database

Synopsis

```
dblink_send_query(text connname, text sql) returns int
```

Description

`dblink_send_query` sends a query to be executed asynchronously, that is, without immediately waiting for the result. There must not be an async query already in progress on the connection.

After successfully dispatching an async query, completion status can be checked with `dblink_is_busy`, and the results are ultimately collected with `dblink_get_result`. It is also possible to attempt to cancel an active async query using `dblink_cancel_query`.

Arguments

`conname`

Name of the connection to use.

`sql`

The SQL statement that you wish to execute in the remote database, for example `select * from pg_class`.

Return Value

Returns 1 if the query was successfully dispatched, 0 otherwise.

Examples

```
SELECT dblink_send_query('dtest1', 'SELECT * FROM foo WHERE f1 < 3');
```

dblink_is_busy

Name

`dblink_is_busy` — checks if connection is busy with an async query

Synopsis

```
dblink_is_busy(text connname) returns int
```

Description

`dblink_is_busy` tests whether an async query is in progress.

Arguments

`conname`

Name of the connection to check.

Return Value

Returns 1 if connection is busy, 0 if it is not busy. If this function returns 0, it is guaranteed that `dblink_get_result` will not block.

Examples

```
SELECT dblink_is_busy('dtest1');
```

dblink_get_notify

Name

dblink_get_notify — retrieve async notifications on a connection

Synopsis

```
dblink_get_notify() returns setof (notify_name text, be_pid int, extra text)
dblink_get_notify(text connname) returns setof (notify_name text, be_pid int, extra text
```

Description

dblink_get_notify retrieves notifications on either the unnamed connection, or on a named connection if specified. To receive notifications via dblink, LISTEN must first be issued, using dblink_exec. For details see LISTEN and NOTIFY.

Arguments

conname

The name of a named connection to get notifications on.

Return Value

Returns setof (notify_name text, be_pid int, extra text), or an empty set if none.

Examples

```
SELECT dblink_exec('LISTEN virtual');
 dblink_exec
-------------
 LISTEN
(1 row)

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-------------+--------+-------
(0 rows)

NOTIFY virtual;
NOTIFY

SELECT * FROM dblink_get_notify();
 notify_name | be_pid | extra
-------------+--------+-------
 virtual     |   1229 |
(1 row)
```

dblink_get_result

Name

dblink_get_result — gets an async query result

Synopsis

```
dblink_get_result(text connname [, bool fail_on_error]) returns setof record
```

Description

dblink_get_result collects the results of an asynchronous query previously sent with dblink_send_query. If the query is not already completed, dblink_get_result will wait until it is.

Arguments

conname

Name of the connection to use.

fail_on_error

If true (the default when omitted) then an error thrown on the remote side of the connection causes an error to also be thrown locally. If false, the remote error is locally reported as a NOTICE, and the function returns no rows.

Return Value

For an async query (that is, a SQL statement returning rows), the function returns the row(s) produced by the query. To use this function, you will need to specify the expected set of columns, as previously discussed for dblink.

For an async command (that is, a SQL statement not returning rows), the function returns a single row with a single text column containing the command's status string. It is still necessary to specify that the result will have a single text column in the calling FROM clause.

Notes

This function *must* be called if dblink_send_query returned 1. It must be called once for each query sent, and one additional time to obtain an empty set result, before the connection can be used again.

When using dblink_send_query and dblink_get_result, dblink fetches the entire remote query result before returning any of it to the local query processor. If the query returns a large number of rows, this can result in transient memory bloat in the local session. It may be better to open such

a query as a cursor with `dblink_open` and then fetch a manageable number of rows at a time. Alternatively, use plain `dblink()`, which avoids memory bloat by spooling large result sets to disk.

Examples

```
contrib_regression=# SELECT dblink_connect('dtest1', 'dbname=contrib_regression');
 dblink_connect
----------------
 OK
(1 row)

contrib_regression=# SELECT * FROM
contrib_regression-# dblink_send_query('dtest1', 'select * from foo where f1 < 3') AS t1
 t1
----
  1
(1 row)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS t1(f1 int, f2 text, f3
 f1 | f2 |     f3
----+----+------------
  0 | a  | {a0,b0,c0}
  1 | b  | {a1,b1,c1}
  2 | c  | {a2,b2,c2}
(3 rows)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS t1(f1 int, f2 text, f3
 f1 | f2 | f3
----+----+----
(0 rows)

contrib_regression=# SELECT * FROM
contrib_regression-# dblink_send_query('dtest1', 'select * from foo where f1 < 3; select
 t1
----
  1
(1 row)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS t1(f1 int, f2 text, f3
 f1 | f2 |     f3
----+----+------------
  0 | a  | {a0,b0,c0}
  1 | b  | {a1,b1,c1}
  2 | c  | {a2,b2,c2}
(3 rows)

contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS t1(f1 int, f2 text, f3
 f1 | f2 |      f3
----+----+---------------
  7 | h  | {a7,b7,c7}
  8 | i  | {a8,b8,c8}
  9 | j  | {a9,b9,c9}
 10 | k  | {a10,b10,c10}
(4 rows)
```

```
contrib_regression=# SELECT * FROM dblink_get_result('dtest1') AS t1(f1 int, f2 text, f3
 f1 | f2 | f3
----+----+----
(0 rows)
```

dblink_cancel_query

Name

dblink_cancel_query — cancels any active query on the named connection

Synopsis

```
dblink_cancel_query(text connname) returns text
```

Description

dblink_cancel_query attempts to cancel any query that is in progress on the named connection. Note that this is not certain to succeed (since, for example, the remote query might already have finished). A cancel request simply improves the odds that the query will fail soon. You must still complete the normal query protocol, for example by calling dblink_get_result.

Arguments

conname

Name of the connection to use.

Return Value

Returns OK if the cancel request has been sent, or the text of an error message on failure.

Examples

```
SELECT dblink_cancel_query('dtest1');
```

dblink_get_pkey

Name

dblink_get_pkey — returns the positions and field names of a relation's primary key fields

Synopsis

```
dblink_get_pkey(text relname) returns setof dblink_pkey_results
```

Description

dblink_get_pkey provides information about the primary key of a relation in the local database. This is sometimes useful in generating queries to be sent to remote databases.

Arguments

relname

Name of a local relation, for example foo or myschema.mytab. Include double quotes if the name is mixed-case or contains special characters, for example "FooBar"; without quotes, the string will be folded to lower case.

Return Value

Returns one row for each primary key field, or no rows if the relation has no primary key. The result row type is defined as

```
CREATE TYPE dblink_pkey_results AS (position int, colname text);
```

The position column simply runs from 1 to *N*; it is the number of the field within the primary key, not the number within the table's columns.

Examples

```
CREATE TABLE foobar (
    f1 int,
    f2 int,
    f3 int,
    PRIMARY KEY (f1, f2, f3)
);
CREATE TABLE

SELECT * FROM dblink_get_pkey('foobar');
 position | colname
----------+---------
        1 | f1
        2 | f2
```

```
        3 | f3
(3 rows)
```

dblink_build_sql_insert

Name

dblink_build_sql_insert — builds an INSERT statement using a local tuple, replacing the primary key field values with alternative supplied values

Synopsis

```
dblink_build_sql_insert(text relname,
                        int2vector primary_key_attnums,
                        integer num_primary_key_atts,
                        text[] src_pk_att_vals_array,
                        text[] tgt_pk_att_vals_array) returns text
```

Description

dblink_build_sql_insert can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL INSERT command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.)

Arguments

relname

Name of a local relation, for example foo or myschema.mytab. Include double quotes if the name is mixed-case or contains special characters, for example "FooBar"; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example 1 2.

num_primary_key_atts

The number of primary key fields.

src_pk_att_vals_array

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

tgt_pk_att_vals_array

Values of the primary key fields to be placed in the resulting INSERT command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in `primary_key_attnums` are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_insert('foo', '1 2', 2, '{"1", "a"}', '{"1", "b"a"}');
             dblink_build_sql_insert
------------------------------------------------
 INSERT INTO foo(f1,f2,f3) VALUES('1','b"a','1')
(1 row)
```

dblink_build_sql_delete

Name

dblink_build_sql_delete — builds a DELETE statement using supplied values for primary key field values

Synopsis

```
dblink_build_sql_delete(text relname,
                        int2vector primary_key_attnums,
                        integer num_primary_key_atts,
                        text[] tgt_pk_att_vals_array) returns text
```

Description

dblink_build_sql_delete can be useful in doing selective replication of a local table to a remote database. It builds a SQL DELETE command that will delete the row with the given primary key values.

Arguments

relname

Name of a local relation, for example foo or myschema.mytab. Include double quotes if the name is mixed-case or contains special characters, for example "FooBar"; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example 1 2.

num_primary_key_atts

The number of primary key fields.

tgt_pk_att_vals_array

Values of the primary key fields to be used in the resulting DELETE command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in primary_key_attnums are interpreted as logical column numbers, corresponding to the column's position in SELECT * FROM relname. Previous

versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_delete('"MyFoo"', '1 2', 2, '{"1", "b"}');
           dblink_build_sql_delete
---------------------------------------------
 DELETE FROM "MyFoo" WHERE f1='1' AND f2='b'
(1 row)
```

dblink_build_sql_update

Name

dblink_build_sql_update — builds an UPDATE statement using a local tuple, replacing the primary key field values with alternative supplied values

Synopsis

```
dblink_build_sql_update(text relname,
                        int2vector primary_key_attnums,
                        integer num_primary_key_atts,
                        text[] src_pk_att_vals_array,
                        text[] tgt_pk_att_vals_array) returns text
```

Description

dblink_build_sql_update can be useful in doing selective replication of a local table to a remote database. It selects a row from the local table based on primary key, and then builds a SQL UPDATE command that will duplicate that row, but with the primary key values replaced by the values in the last argument. (To make an exact copy of the row, just specify the same values for the last two arguments.) The UPDATE command always assigns all fields of the row — the main difference between this and dblink_build_sql_insert is that it's assumed that the target row already exists in the remote table.

Arguments

relname

Name of a local relation, for example foo or myschema.mytab. Include double quotes if the name is mixed-case or contains special characters, for example "FooBar"; without quotes, the string will be folded to lower case.

primary_key_attnums

Attribute numbers (1-based) of the primary key fields, for example 1 2.

num_primary_key_atts

The number of primary key fields.

src_pk_att_vals_array

Values of the primary key fields to be used to look up the local tuple. Each field is represented in text form. An error is thrown if there is no local row with these primary key values.

tgt_pk_att_vals_array

Values of the primary key fields to be placed in the resulting UPDATE command. Each field is represented in text form.

Return Value

Returns the requested SQL statement as text.

Notes

As of PostgreSQL 9.0, the attribute numbers in `primary_key_attnums` are interpreted as logical column numbers, corresponding to the column's position in `SELECT * FROM relname`. Previous versions interpreted the numbers as physical column positions. There is a difference if any column(s) to the left of the indicated column have been dropped during the lifetime of the table.

Examples

```
SELECT dblink_build_sql_update('foo', '1 2', 2, '{"1", "a"}', '{"1", "b"}');
                   dblink_build_sql_update
-------------------------------------------------------------
 UPDATE foo SET f1='1',f2='b',f3='1' WHERE f1='1' AND f2='b'
(1 row)
```

F.10. dict_int

dict_int is an example of an add-on dictionary template for full-text search. The motivation for this example dictionary is to control the indexing of integers (signed and unsigned), allowing such numbers to be indexed while preventing excessive growth in the number of unique words, which greatly affects the performance of searching.

F.10.1. Configuration

The dictionary accepts two options:

- The maxlen parameter specifies the maximum number of digits allowed in an integer word. The default value is 6.
- The rejectlong parameter specifies whether an overlength integer should be truncated or ignored. If rejectlong is false (the default), the dictionary returns the first maxlen digits of the integer. If rejectlong is true, the dictionary treats an overlength integer as a stop word, so that it will not be indexed. Note that this also means that such an integer cannot be searched for.

F.10.2. Usage

Installing the dict_int extension creates a text search template intdict_template and a dictionary intdict based on it, with the default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY intdict (MAXLEN = 4, REJECTLONG = true);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb# select ts_lexize('intdict', '12345678');
 ts_lexize
-----------
 {123456}
```

but real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:

```
ALTER TEXT SEARCH CONFIGURATION english
    ALTER MAPPING FOR int, uint WITH intdict;
```

F.11. dict_xsyn

dict_xsyn (Extended Synonym Dictionary) is an example of an add-on dictionary template for full-text search. This dictionary type replaces words with groups of their synonyms, and so makes it possible to search for a word using any of its synonyms.

F.11.1. Configuration

A dict_xsyn dictionary accepts the following options:

- matchorig controls whether the original word is accepted by the dictionary. Default is true.
- matchsynonyms controls whether the synonyms are accepted by the dictionary. Default is false.
- keeporig controls whether the original word is included in the dictionary's output. Default is true.
- keepsynonyms controls whether the synonyms are included in the dictionary's output. Default is true.
- rules is the base name of the file containing the list of synonyms. This file must be stored in $SHAREDIR/tsearch_data/ (where $SHAREDIR means the PostgreSQL installation's shared-data directory). Its name must end in .rules (which is not to be included in the rules parameter).

The rules file has the following format:

- Each line represents a group of synonyms for a single word, which is given first on the line. Synonyms are separated by whitespace, thus:

  ```
  word syn1 syn2 syn3
  ```

- The sharp (#) sign is a comment delimiter. It may appear at any position in a line. The rest of the line will be skipped.

Look at xsyn_sample.rules, which is installed in $SHAREDIR/tsearch_data/, for an example.

F.11.2. Usage

Installing the dict_xsyn extension creates a text search template xsyn_template and a dictionary xsyn based on it, with default parameters. You can alter the parameters, for example

```
mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules', KEEPORIG=false);
ALTER TEXT SEARCH DICTIONARY
```

or create new dictionaries based on the template.

To test the dictionary, you can try

```
mydb=# SELECT ts_lexize('xsyn', 'word');
      ts_lexize
-----------------------
 {syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules', KEEPORIG=true);
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'word');
      ts_lexize
-----------------------
 {word,syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules', KEEPORIG=false, MATCHSYNONYMS
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
```

```
      ts_lexize
-----------------------
 {syn1,syn2,syn3}

mydb# ALTER TEXT SEARCH DICTIONARY xsyn (RULES='my_rules', KEEPORIG=true, MATCHORIG=fals
ALTER TEXT SEARCH DICTIONARY

mydb=# SELECT ts_lexize('xsyn', 'syn1');
      ts_lexize
-----------------------
 {word}
```

Real-world usage will involve including it in a text search configuration as described in Chapter 12. That might look like this:

```
ALTER TEXT SEARCH CONFIGURATION english
    ALTER MAPPING FOR word, asciiword WITH xsyn, english_stem;
```

F.12. dummy_seclabel

The `dummy_seclabel` module exists only to support regression testing of the `SECURITY LABEL` statement. It is not intended to be used in production.

F.12.1. Rationale

The `SECURITY LABEL` statement allows the user to assign security labels to database objects; however, security labels can only be assigned when specifically allowed by a loadable module, so this module is provided to allow proper regression testing.

Security label providers intended to be used in production will typically be dependent on a platform-specific feature such as SE-Linux. This module is platform-independent, and therefore better-suited to regression testing.

F.12.2. Usage

Here's a simple example of usage:

```
# postgresql.conf
shared_preload_libraries = 'dummy_seclabel'

postgres=# CREATE TABLE t (a int, b text);
CREATE TABLE
postgres=# SECURITY LABEL ON TABLE t IS 'classified';
SECURITY LABEL
```

The `dummy_seclabel` module provides only four hardcoded labels: `unclassified`, `classified`, `secret`, and `top secret`. It does not allow any other strings as security labels.

These labels are not used to enforce access controls. They are only used to check whether the `SECURITY LABEL` statement works as expected, or not.

F.12.3. Author

KaiGai Kohei <kaigai@ak.jp.nec.com>

F.13. earthdistance

The earthdistance module provides two different approaches to calculating great circle distances on the surface of the Earth. The one described first depends on the cube module (which *must* be installed before earthdistance can be installed). The second one is based on the built-in point data type, using longitude and latitude for the coordinates.

In this module, the Earth is assumed to be perfectly spherical. (If that's too inaccurate for you, you might want to look at the PostGIS[1] project.)

F.13.1. Cube-based Earth Distances

Data is stored in cubes that are points (both corners are the same) using 3 coordinates representing the x, y, and z distance from the center of the Earth. A domain earth over cube is provided, which includes constraint checks that the value meets these restrictions and is reasonably close to the actual surface of the Earth.

The radius of the Earth is obtained from the earth() function. It is given in meters. But by changing this one function you can change the module to use some other units, or to use a different value of the radius that you feel is more appropriate.

This package has applications to astronomical databases as well. Astronomers will probably want to change earth() to return a radius of 180/pi() so that distances are in degrees.

Functions are provided to support input in latitude and longitude (in degrees), to support output of latitude and longitude, to calculate the great circle distance between two points and to easily specify a bounding box usable for index searches.

The provided functions are shown in Table F-4.

Table F-4. Cube-based Earthdistance Functions

Function	Returns	Description
earth()	float8	Returns the assumed radius of the Earth.
sec_to_gc(float8)	float8	Converts the normal straight line (secant) distance between two points on the surface of the Earth to the great circle distance between them.
gc_to_sec(float8)	float8	Converts the great circle distance between two points on the surface of the Earth to the normal straight line (secant) distance between them.

1. http://www.postgis.org/

Function	Returns	Description
`ll_to_earth(float8, float8)`	`earth`	Returns the location of a point on the surface of the Earth given its latitude (argument 1) and longitude (argument 2) in degrees.
`latitude(earth)`	`float8`	Returns the latitude in degrees of a point on the surface of the Earth.
`longitude(earth)`	`float8`	Returns the longitude in degrees of a point on the surface of the Earth.
`earth_distance(earth, earth)`	`float8`	Returns the great circle distance between two points on the surface of the Earth.
`earth_box(earth, float8)`	`cube`	Returns a box suitable for an indexed search using the cube `@>` operator for points within a given great circle distance of a location. Some points in this box are further than the specified great circle distance from the location, so a second check using `earth_distance` should be included in the query.

F.13.2. Point-based Earth Distances

The second part of the module relies on representing Earth locations as values of type `point`, in which the first component is taken to represent longitude in degrees, and the second component is taken to represent latitude in degrees. Points are taken as (longitude, latitude) and not vice versa because longitude is closer to the intuitive idea of x-axis and latitude to y-axis.

A single operator is provided, shown in Table F-5.

Table F-5. Point-based Earthdistance Operators

Operator	Returns	Description
`point <@> point`	`float8`	Gives the distance in statute miles between two points on the Earth's surface.

Note that unlike the `cube`-based part of the module, units are hardwired here: changing the `earth()` function will not affect the results of this operator.

One disadvantage of the longitude/latitude representation is that you need to be careful about the edge conditions near the poles and near +/- 180 degrees of longitude. The `cube`-based representation avoids these discontinuities.

F.14. file_fdw

The file_fdw module provides the foreign-data wrapper file_fdw, which can be used to access data files in the server's file system. Data files must be in a format that can be read by COPY FROM; see COPY for details. Access to such data files is currently read-only.

A foreign table created using this wrapper can have the following options:

filename

Specifies the file to be read. Required. Must be an absolute path name.

format

Specifies the file's format, the same as COPY's FORMAT option.

header

Specifies whether the file has a header line, the same as COPY's HEADER option.

delimiter

Specifies the file's delimiter character, the same as COPY's DELIMITER option.

quote

Specifies the file's quote character, the same as COPY's QUOTE option.

escape

Specifies the file's escape character, the same as COPY's ESCAPE option.

null

Specifies the file's null string, the same as COPY's NULL option.

encoding

Specifies the file's encoding, the same as COPY's ENCODING option.

Note that while COPY allows options such as OIDS and HEADER to be specified without a corresponding value, the foreign data wrapper syntax requires a value to be present in all cases. To activate COPY options normally supplied without a value, you can instead pass the value TRUE.

A column of a foreign table created using this wrapper can have the following options:

force_not_null

This is a Boolean option. If true, it specifies that values of the column should not be matched against the null string (that is, the file-level null option). This has the same effect as listing the column in COPY's FORCE_NOT_NULL option.

force_null

This is a Boolean option. If true, it specifies that values of the column which match the null string are returned as NULL even if the value is quoted. Without this option, only unquoted values matching the null string are returned as NULL. This has the same effect as listing the column in COPY's FORCE_NULL option.

COPY's OIDS and FORCE_QUOTE options are currently not supported by file_fdw.

These options can only be specified for a foreign table or its columns, not in the options of the file_fdw foreign-data wrapper, nor in the options of a server or user mapping using the wrapper.

Changing table-level options requires superuser privileges, for security reasons: only a superuser should be able to determine which file is read. In principle non-superusers could be allowed to change the other options, but that's not supported at present.

For a foreign table using `file_fdw`, `EXPLAIN` shows the name of the file to be read. Unless `COSTS OFF` is specified, the file size (in bytes) is shown as well.

Example F-1. Create a Foreign Table for PostgreSQL CSV Logs

One of the obvious uses for the `file_fdw` is to make the PostgreSQL activity log available as a table for querying. To do this, first you must be logging to a CSV file, which here we will call `pglog.csv`. First, install `file_fdw` as an extension:

```
CREATE EXTENSION file_fdw;
```

Then create a foreign server:

```
CREATE SERVER pglog FOREIGN DATA WRAPPER file_fdw;
```

Now you are ready to create the foreign data table. Using the `CREATE FOREIGN TABLE` command, you will need to define the columns for the table, the CSV file name, and its format:

```
CREATE FOREIGN TABLE pglog (
  log_time timestamp(3) with time zone,
  user_name text,
  database_name text,
  process_id integer,
  connection_from text,
  session_id text,
  session_line_num bigint,
  command_tag text,
  session_start_time timestamp with time zone,
  virtual_transaction_id text,
  transaction_id bigint,
  error_severity text,
  sql_state_code text,
  message text,
  detail text,
  hint text,
  internal_query text,
  internal_query_pos integer,
  context text,
  query text,
  query_pos integer,
  location text,
  application_name text
) SERVER pglog
OPTIONS ( filename '/home/josh/9.1/data/pg_log/pglog.csv', format 'csv' );
```

That's it — now you can query your log directly. In production, of course, you would need to define some way to deal with log rotation.

F.15. fuzzystrmatch

The `fuzzystrmatch` module provides several functions to determine similarities and distance between strings.

> **Caution**
>
> At present, the `soundex`, `metaphone`, `dmetaphone`, and `dmetaphone_alt` functions do not work well with multibyte encodings (such as UTF-8).

F.15.1. Soundex

The Soundex system is a method of matching similar-sounding names by converting them to the same code. It was initially used by the United States Census in 1880, 1900, and 1910. Note that Soundex is not very useful for non-English names.

The `fuzzystrmatch` module provides two functions for working with Soundex codes:

```
soundex(text) returns text
difference(text, text) returns int
```

The `soundex` function converts a string to its Soundex code. The `difference` function converts two strings to their Soundex codes and then reports the number of matching code positions. Since Soundex codes have four characters, the result ranges from zero to four, with zero being no match and four being an exact match. (Thus, the function is misnamed — `similarity` would have been a better name.)

Here are some usage examples:

```
SELECT soundex('hello world!');

SELECT soundex('Anne'), soundex('Ann'), difference('Anne', 'Ann');
SELECT soundex('Anne'), soundex('Andrew'), difference('Anne', 'Andrew');
SELECT soundex('Anne'), soundex('Margaret'), difference('Anne', 'Margaret');

CREATE TABLE s (nm text);

INSERT INTO s VALUES ('john');
INSERT INTO s VALUES ('joan');
INSERT INTO s VALUES ('wobbly');
INSERT INTO s VALUES ('jack');

SELECT * FROM s WHERE soundex(nm) = soundex('john');

SELECT * FROM s WHERE difference(s.nm, 'john') > 2;
```

F.15.2. Levenshtein

This function calculates the Levenshtein distance between two strings:

```
levenshtein(text source, text target, int ins_cost, int del_cost, int sub_cost) returns
levenshtein(text source, text target) returns int
levenshtein_less_equal(text source, text target, int ins_cost, int del_cost, int sub_cos
levenshtein_less_equal(text source, text target, int max_d) returns int
```

Both `source` and `target` can be any non-null string, with a maximum of 255 bytes. The cost parameters specify how much to charge for a character insertion, deletion, or substitution, respectively. You can omit the cost parameters, as in the second version of the function; in that case they all default to 1. `levenshtein_less_equal` is accelerated version of levenshtein function for low values

of distance. If actual distance is less or equal then max_d, then `levenshtein_less_equal` returns accurate value of it. Otherwise this function returns value which is greater than max_d.

Examples:

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL');
 levenshtein
-------------
           2
(1 row)

test=# SELECT levenshtein('GUMBO', 'GAMBOL', 2,1,1);
 levenshtein
-------------
           3
(1 row)

test=# SELECT levenshtein_less_equal('extensive', 'exhaustive',2);
 levenshtein_less_equal
------------------------
                      3
(1 row)

test=# SELECT levenshtein_less_equal('extensive', 'exhaustive',4);
 levenshtein_less_equal
------------------------
                      4
(1 row)
```

F.15.3. Metaphone

Metaphone, like Soundex, is based on the idea of constructing a representative code for an input string. Two strings are then deemed similar if they have the same codes.

This function calculates the metaphone code of an input string:

```
metaphone(text source, int max_output_length) returns text
```

`source` has to be a non-null string with a maximum of 255 characters. `max_output_length` sets the maximum length of the output metaphone code; if longer, the output is truncated to this length.

Example:

```
test=# SELECT metaphone('GUMBO', 4);
 metaphone
-----------
 KM
(1 row)
```

F.15.4. Double Metaphone

The Double Metaphone system computes two "sounds like" strings for a given input string — a "primary" and an "alternate". In most cases they are the same, but for non-English names especially they can be a bit different, depending on pronunciation. These functions compute the primary and alternate codes:

```
dmetaphone(text source) returns text
dmetaphone_alt(text source) returns text
```

There is no length limit on the input strings.

Example:

```
test=# select dmetaphone('gumbo');
 dmetaphone
------------
 KMP
(1 row)
```

F.16. hstore

This module implements the `hstore` data type for storing sets of key/value pairs within a single PostgreSQL value. This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data. Keys and values are simply text strings.

F.16.1. `hstore` External Representation

The text representation of an `hstore`, used for input and output, includes zero or more *`key`* `=>` *`value`* pairs separated by commas. Some examples:

```
k => v
foo => bar, baz => whatever
"1-a" => "anything at all"
```

The order of the pairs is not significant (and may not be reproduced on output). Whitespace between pairs or around the => sign is ignored. Double-quote keys and values that include whitespace, commas, =s or >s. To include a double quote or a backslash in a key or value, escape it with a backslash.

Each key in an `hstore` is unique. If you declare an `hstore` with duplicate keys, only one will be stored in the `hstore` and there is no guarantee as to which will be kept:

```
SELECT 'a=>1,a=>2'::hstore;
  hstore
----------
 "a"=>"1"
```

A value (but not a key) can be an SQL `NULL`. For example:

```
key => NULL
```

The `NULL` keyword is case-insensitive. Double-quote the `NULL` to treat it as the ordinary string "NULL".

> **Note:** Keep in mind that the `hstore` text format, when used for input, applies *before* any required quoting or escaping. If you are passing an `hstore` literal via a parameter, then no additional processing is needed. But if you're passing it as a quoted literal constant, then any single-quote characters and (depending on the setting of the `standard_conforming_strings` configuration

parameter) backslash characters need to be escaped correctly. See Section 4.1.2.1 for more on the handling of string constants.

On output, double quotes always surround keys and values, even when it's not strictly necessary.

F.16.2. `hstore` Operators and Functions

The operators provided by the `hstore` module are shown in Table F-6, the functions in Table F-7.

Table F-6. `hstore` Operators

Operator	Description	Example	Result
`hstore -> text`	get value for key (`NULL` if not present)	`'a=>x, b=>y'::hstore -> 'a'`	`x`
`hstore -> text[]`	get values for keys (`NULL` if not present)	`'a=>x, b=>y, c=>z'::hstore -> ARRAY['c','a']`	`{"z","x"}`
`hstore || hstore`	concatenate `hstore`s	`'a=>b, c=>d'::hstore || 'c=>x, d=>q'::hstore`	`"a"=>"b", "c"=>"x", "d"=>"q"`
`hstore ? text`	does `hstore` contain key?	`'a=>1'::hstore ? 'a'`	`t`
`hstore ?& text[]`	does `hstore` contain all specified keys?	`'a=>1,b=>2'::hstore ?& ARRAY['a','b']`	`t`
`hstore ?| text[]`	does `hstore` contain any of the specified keys?	`'a=>1,b=>2'::hstore ?| ARRAY['b','c']`	`t`
`hstore @> hstore`	does left operand contain right?	`'a=>b, b=>1, c=>NULL'::hstore @> 'b=>1'`	`t`
`hstore <@ hstore`	is left operand contained in right?	`'a=>c'::hstore <@ 'a=>b, b=>1, c=>NULL'`	`f`
`hstore - text`	delete key from left operand	`'a=>1, b=>2, c=>3'::hstore - 'b'::text`	`"a"=>"1", "c"=>"3"`
`hstore - text[]`	delete keys from left operand	`'a=>1, b=>2, c=>3'::hstore - ARRAY['a','b']`	`"c"=>"3"`
`hstore - hstore`	delete matching pairs from left operand	`'a=>1, b=>2, c=>3'::hstore - 'a=>4, b=>2'::hstore`	`"a"=>"1", "c"=>"3"`

Operator	Description	Example	Result
`record #= hstore`	replace fields in `record` with matching values from `hstore`	see Examples section	
`%% hstore`	convert `hstore` to array of alternating keys and values	`%% 'a=>foo, b=>bar'::hstore`	`{a,foo,b,bar}`
`%# hstore`	convert `hstore` to two-dimensional key/value array	`%# 'a=>foo, b=>bar'::hstore`	`{{a,foo},{b,bar}}`

Note: Prior to PostgreSQL 8.2, the containment operators `@>` and `<@` were called `@` and `~`, respectively. These names are still available, but are deprecated and will eventually be removed. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!

Table F-7. `hstore` Functions

Function	Return Type	Description	Example	Result
`hstore(record)`	`hstore`	construct an `hstore` from a record or row	`hstore(ROW(1,2))`	`f1=>1,f2=>2`
`hstore(text[])`	`hstore`	construct an `hstore` from an array, which may be either a key/value array, or a two-dimensional array	`hstore(ARRAY['a','1','b','2'])` `||` `hstore(ARRAY[['c','3'],['d','4']])`	`a=>1, b=>2, c=>3, d=>4`
`hstore(text[], text[])`	`hstore`	construct an `hstore` from separate key and value arrays	`hstore(ARRAY['a','b'], ARRAY['1','2'])`	`"a"=>"1","b"=>"2"`
`hstore(text, text)`	`hstore`	make single-item `hstore`	`hstore('a', 'b')`	`"a"=>"b"`
`akeys(hstore)`	`text[]`	get `hstore`'s keys as an array	`akeys('a=>1,b=>2')`	`{a,b}`
`skeys(hstore)`	`setof text`	get `hstore`'s keys as a set	`skeys('a=>1,b=>2')`	`a` `b`
`avals(hstore)`	`text[]`	get `hstore`'s values as an array	`avals('a=>1,b=>2')`	`{1,2}`
`svals(hstore)`	`setof text`	get `hstore`'s values as a set	`svals('a=>1,b=>2')`	`1` `2`

Function	Return Type	Description	Example	Result
`hstore_to_array(hstore)`	`text[]`	get `hstore`'s keys and values as an array of alternating keys and values	`hstore_to_array('a=>1,b=>2')`	`{a,1,b,2}`
`hstore_to_matrix(hstore)`	`text[]`	get `hstore`'s keys and values as a two-dimensional array	`hstore_to_matrix('a=>1,b=>2')`	`{{a,1},{b,2}}`
`hstore_to_json(hstore)`	`json`	get `hstore` as a `json` value	`hstore_to_json('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e+4')`	`{"a key": "1", "b": "t", "c": null, "d": "12345", "e": "012345", "f": "1.234", "g": "2.345e+4"}`
`hstore_to_json_loose(hstore)`	`json`	get `hstore` as a `json` value, but attempt to distinguish numerical and Boolean values so they are unquoted in the JSON	`hstore_to_json_loose('"a key"=>1, b=>t, c=>null, d=>12345, e=>012345, f=>1.234, g=>2.345e+4')`	`{"a key": 1, "b": true, "c": null, "d": 12345, "e": "012345", "f": 1.234, "g": 2.345e+4}`
`slice(hstore, text[])`	`hstore`	extract a subset of an `hstore`	`slice('a=>1,b=>2,c=>3'::hstore, ARRAY['b','c','x'])`	`"b"=>"2", "c"=>"3"`

`each(hstore)`	`setof(key text, value text)`	get `hstore`'s keys and values as a set	`select * from each('a=>1,b=>2')`	`key | value`
				`-----+-------`
				`a | 1`
				`b | 2`

`exist(hstore,text)`	`boolean`	does `hstore` contain key?	`exist('a=>1','a')`	`t`
`defined(hstore,text)`	`boolean`	does `hstore` contain non-`NULL` value for key?	`defined('a=>NULL','a')`	`f`
`delete(hstore,text)`	`hstore`	delete pair with matching key	`delete('a=>1,b=>2','b')`	`"a"=>"1"`
`delete(hstore,text[])`	`hstore`	delete pairs with matching keys	`delete('a=>1,b=>2,c=>3','{a,b}')`	`"c"=>"3"`
`delete(hstore,hstore)`	`hstore`	delete pairs matching those in the second argument	`delete('a=>1,b=>2','a=>4,b=>2'::hstore)`	`"a"=>"1"`

Function	Return Type	Description	Example	Result
`populate_record(record,hstore)`	`record`	replace fields in `record` with matching values from `hstore`	see Examples section	

Note: The function `hstore_to_json` is used when an `hstore` value is cast to `json`.

Note: The function `populate_record` is actually declared with `anyelement`, not `record`, as its first argument, but it will reject non-record types with a run-time error.

F.16.3. Indexes

`hstore` has GiST and GIN index support for the `@>`, `?`, `?&` and `?|` operators. For example:

```
CREATE INDEX hidx ON testhstore USING GIST (h);

CREATE INDEX hidx ON testhstore USING GIN (h);
```

`hstore` also supports `btree` or `hash` indexes for the = operator. This allows `hstore` columns to be declared `UNIQUE`, or to be used in `GROUP BY`, `ORDER BY` or `DISTINCT` expressions. The sort ordering for `hstore` values is not particularly useful, but these indexes may be useful for equivalence lookups. Create indexes for = comparisons as follows:

```
CREATE INDEX hidx ON testhstore USING BTREE (h);

CREATE INDEX hidx ON testhstore USING HASH (h);
```

F.16.4. Examples

Add a key, or update an existing key with a new value:

```
UPDATE tab SET h = h || hstore('c', '3');
```

Delete a key:

```
UPDATE tab SET h = delete(h, 'k1');
```

Convert a `record` to an `hstore`:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');

SELECT hstore(t) FROM test AS t;
                  hstore
```

```
-----------------------------------------
 "col1"=>"123", "col2"=>"foo", "col3"=>"bar"
(1 row)
```

Convert an `hstore` to a predefined `record` type:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);

SELECT * FROM populate_record(null::test,
                              '"col1"=>"456", "col2"=>"zzz"');
 col1 | col2 | col3
------+------+------
  456 | zzz  |
(1 row)
```

Modify an existing record using the values from an `hstore`:

```
CREATE TABLE test (col1 integer, col2 text, col3 text);
INSERT INTO test VALUES (123, 'foo', 'bar');

SELECT (r).* FROM (SELECT t #= '"col3"=>"baz"' AS r FROM test t) s;
 col1 | col2 | col3
------+------+------
  123 | foo  | baz
(1 row)
```

F.16.5. Statistics

The `hstore` type, because of its intrinsic liberality, could contain a lot of different keys. Checking for valid keys is the task of the application. The following examples demonstrate several techniques for checking keys and obtaining statistics.

Simple example:

```
SELECT * FROM each('aaa=>bq, b=>NULL, ""=>1');
```

Using a table:

```
SELECT (each(h)).key, (each(h)).value INTO stat FROM testhstore;
```

Online statistics:

```
SELECT key, count(*) FROM
  (SELECT (each(h)).key FROM testhstore) AS stat
  GROUP BY key
  ORDER BY count DESC, key;
    key    | count
-----------+-------
 line      |   883
```

```
 query      |   207
 pos        |   203
 node       |   202
 space      |   197
 status     |   195
 public     |   194
 title      |   190
 org        |   189
.................
```

F.16.6. Compatibility

As of PostgreSQL 9.0, `hstore` uses a different internal representation than previous versions. This presents no obstacle for dump/restore upgrades since the text representation (used in the dump) is unchanged.

In the event of a binary upgrade, upward compatibility is maintained by having the new code recognize old-format data. This will entail a slight performance penalty when processing data that has not yet been modified by the new code. It is possible to force an upgrade of all values in a table column by doing an `UPDATE` statement as follows:

```
UPDATE tablename SET hstorecol = hstorecol || '';
```

Another way to do it is:

```
ALTER TABLE tablename ALTER hstorecol TYPE hstore USING hstorecol || '';
```

The `ALTER TABLE` method requires an exclusive lock on the table, but does not result in bloating the table with old row versions.

F.16.7. Authors

Oleg Bartunov <`oleg@sai.msu.su`>, Moscow, Moscow University, Russia

Teodor Sigaev <`teodor@sigaev.ru`>, Moscow, Delta-Soft Ltd., Russia

Additional enhancements by Andrew Gierth <`andrew@tao11.riddles.org.uk`>, United Kingdom

F.17. intagg

The `intagg` module provides an integer aggregator and an enumerator. `intagg` is now obsolete, because there are built-in functions that provide a superset of its capabilities. However, the module is still provided as a compatibility wrapper around the built-in functions.

F.17.1. Functions

The aggregator is an aggregate function `int_array_aggregate(integer)` that produces an integer array containing exactly the integers it is fed. This is a wrapper around `array_agg`, which does the same thing for any array type.

The enumerator is a function `int_array_enum(integer[])` that returns `setof integer`. It is essentially the reverse operation of the aggregator: given an array of integers, expand it into a set of rows. This is a wrapper around `unnest`, which does the same thing for any array type.

F.17.2. Sample Uses

Many database systems have the notion of a one to many table. Such a table usually sits between two indexed tables, for example:

```
CREATE TABLE left (id INT PRIMARY KEY, ...);
CREATE TABLE right (id INT PRIMARY KEY, ...);
CREATE TABLE one_to_many(left INT REFERENCES left, right INT REFERENCES right);
```

It is typically used like this:

```
SELECT right.* from right JOIN one_to_many ON (right.id = one_to_many.right)
  WHERE one_to_many.left = item;
```

This will return all the items in the right hand table for an entry in the left hand table. This is a very common construct in SQL.

Now, this methodology can be cumbersome with a very large number of entries in the `one_to_many` table. Often, a join like this would result in an index scan and a fetch for each right hand entry in the table for a particular left hand entry. If you have a very dynamic system, there is not much you can do. However, if you have some data which is fairly static, you can create a summary table with the aggregator.

```
CREATE TABLE summary AS
  SELECT left, int_array_aggregate(right) AS right
  FROM one_to_many
  GROUP BY left;
```

This will create a table with one row per left item, and an array of right items. Now this is pretty useless without some way of using the array; that's why there is an array enumerator. You can do

```
SELECT left, int_array_enum(right) FROM summary WHERE left = item;
```

The above query using `int_array_enum` produces the same results as

```
SELECT left, right FROM one_to_many WHERE left = item;
```

The difference is that the query against the summary table has to get only one row from the table, whereas the direct query against `one_to_many` must index scan and fetch a row for each entry.

On one system, an `EXPLAIN` showed a query with a cost of 8488 was reduced to a cost of 329. The original query was a join involving the `one_to_many` table, which was replaced by:

```
SELECT right, count(right) FROM
  ( SELECT left, int_array_enum(right) AS right
    FROM summary JOIN (SELECT left FROM left_table WHERE left = item) AS lefts
         ON (summary.left = lefts.left)
```

```
) AS list
GROUP BY right
ORDER BY count DESC;
```

F.18. intarray

The intarray module provides a number of useful functions and operators for manipulating null-free arrays of integers. There is also support for indexed searches using some of the operators.

All of these operations will throw an error if a supplied array contains any NULL elements.

Many of these operations are only sensible for one-dimensional arrays. Although they will accept input arrays of more dimensions, the data is treated as though it were a linear array in storage order.

F.18.1. intarray Functions and Operators

The functions provided by the intarray module are shown in Table F-8, the operators in Table F-9.

Table F-8. intarray Functions

Function	Return Type	Description	Example	Result
icount(int[])	int	number of elements in array	icount('{1,2,3}'::int[])	3
sort(int[], text dir)	int[]	sort array — dir must be asc or desc	sort('{1,2,3}'::int[], 'desc')	{3,2,1}
sort(int[])	int[]	sort in ascending order	sort(array[11,77,44])	{11,44,77}
sort_asc(int[])	int[]	sort in ascending order		
sort_desc(int[])	int[]	sort in descending order		
uniq(int[])	int[]	remove adjacent duplicates	uniq(sort('{1,2,3}'::int[]))	{1,2,3}
idx(int[], int item)	int	index of first element matching item (0 if none)	idx(array[11,22,33,22,11], 22)	2
subarray(int[], int start, int len)	int[]	portion of array starting at position start, len elements	subarray('{1,2,3,2,1}'::int[], 2, 3)	{2,3,2}
subarray(int[], int start)	int[]	portion of array starting at position start	subarray('{1,2,3,2,1}'::int[], 2)	{2,3,2,1}

Function	Return Type	Description	Example	Result
`intset(int)`	`int[]`	make single-element array	`intset(42)`	`{42}`

Table F-9. `intarray` Operators

Operator	Returns	Description
`int[] && int[]`	`boolean`	overlap — `true` if arrays have at least one common element
`int[] @> int[]`	`boolean`	contains — `true` if left array contains right array
`int[] <@ int[]`	`boolean`	contained — `true` if left array is contained in right array
`# int[]`	`int`	number of elements in array
`int[] # int`	`int`	index (same as `idx` function)
`int[] + int`	`int[]`	push element onto array (add it to end of array)
`int[] + int[]`	`int[]`	array concatenation (right array added to the end of left one)
`int[] - int`	`int[]`	remove entries matching right argument from array
`int[] - int[]`	`int[]`	remove elements of right array from left
`int[] | int`	`int[]`	union of arguments
`int[] | int[]`	`int[]`	union of arrays
`int[] & int[]`	`int[]`	intersection of arrays
`int[] @@ query_int`	`boolean`	`true` if array satisfies query (see below)
`query_int ~~ int[]`	`boolean`	`true` if array satisfies query (commutator of `@@`)

(Before PostgreSQL 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The operators `&&`, `@>` and `<@` are equivalent to PostgreSQL's built-in operators of the same names, except that they work only on integer arrays that do not contain nulls, while the built-in operators work for any array type. This restriction makes them faster than the built-in operators in many cases.

The `@@` and `~~` operators test whether an array satisfies a *query*, which is expressed as a value of a specialized data type `query_int`. A *query* consists of integer values that are checked against the elements of the array, possibly combined using the operators `&` (AND), `|` (OR), and `!` (NOT). Parentheses can be used as needed. For example, the query `1&(2|3)` matches arrays that contain 1 and also contain either 2 or 3.

F.18.2. Index Support

intarray provides index support for the &&, @>, <@, and @@ operators, as well as regular array equality.

Two GiST index operator classes are provided: gist__int_ops (used by default) is suitable for small- to medium-size data sets, while gist__intbig_ops uses a larger signature and is more suitable for indexing large data sets (i.e., columns containing a large number of distinct array values). The implementation uses an RD-tree data structure with built-in lossy compression.

There is also a non-default GIN operator class gin__int_ops supporting the same operators.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere. As a rule of thumb, a GIN index is faster to search than a GiST index, but slower to build or update; so GIN is better suited for static data and GiST for often-updated data.

F.18.3. Example

```
-- a message can be in one or more "sections"
CREATE TABLE message (mid INT PRIMARY KEY, sections INT[], ...);

-- create specialized index
CREATE INDEX message_rdtree_idx ON message USING GIST (sections gist__int_ops);

-- select messages in section 1 OR 2 - OVERLAP operator
SELECT message.mid FROM message WHERE message.sections && '{1,2}';

-- select messages in sections 1 AND 2 - CONTAINS operator
SELECT message.mid FROM message WHERE message.sections @> '{1,2}';

-- the same, using QUERY operator
SELECT message.mid FROM message WHERE message.sections @@ '1&2'::query_int;
```

F.18.4. Benchmark

The source directory contrib/intarray/bench contains a benchmark test suite. To run:

```
cd .../bench
createdb TEST
psql TEST < ../_int.sql
./create_test.pl | psql TEST
./bench.pl
```

The bench.pl script has numerous options, which are displayed when it is run without any arguments.

F.18.5. Authors

All work was done by Teodor Sigaev (<teodor@sigaev.ru>) and Oleg Bartunov (<oleg@sai.msu.su>). See http://www.sai.msu.su/~megera/postgres/gist/ for additional information. Andrey Oktyabrski did a great work on adding new functions and operations.

F.19. isn

The `isn` module provides data types for the following international product numbering standards: EAN13, UPC, ISBN (books), ISMN (music), and ISSN (serials). Numbers are validated on input according to a hard-coded list of prefixes; this list of prefixes is also used to hyphenate numbers on output. Since new prefixes are assigned from time to time, the list of prefixes may be out of date. It is hoped that a future version of this module will obtained the prefix list from one or more tables that can be easily updated by users as needed; however, at present, the list can only be updated by modifying the source code and recompiling. Alternatively, prefix validation and hyphenation support may be dropped from a future version of this module.

F.19.1. Data Types

Table F-10 shows the data types provided by the `isn` module.

Table F-10. `isn` Data Types

Data Type	Description
`EAN13`	European Article Numbers, always displayed in the EAN13 display format
`ISBN13`	International Standard Book Numbers to be displayed in the new EAN13 display format
`ISMN13`	International Standard Music Numbers to be displayed in the new EAN13 display format
`ISSN13`	International Standard Serial Numbers to be displayed in the new EAN13 display format
`ISBN`	International Standard Book Numbers to be displayed in the old short display format
`ISMN`	International Standard Music Numbers to be displayed in the old short display format
`ISSN`	International Standard Serial Numbers to be displayed in the old short display format
`UPC`	Universal Product Codes

Some notes:

1. ISBN13, ISMN13, ISSN13 numbers are all EAN13 numbers.
2. EAN13 numbers aren't always ISBN13, ISMN13 or ISSN13 (some are).
3. Some ISBN13 numbers can be displayed as ISBN.
4. Some ISMN13 numbers can be displayed as ISMN.
5. Some ISSN13 numbers can be displayed as ISSN.
6. UPC numbers are a subset of the EAN13 numbers (they are basically EAN13 without the first `0` digit).
7. All UPC, ISBN, ISMN and ISSN numbers can be represented as EAN13 numbers.

Internally, all these types use the same representation (a 64-bit integer), and all are interchangeable. Multiple types are provided to control display formatting and to permit tighter validity checking of input that is supposed to denote one particular type of number.

The ISBN, ISMN, and ISSN types will display the short version of the number (ISxN 10) whenever it's possible, and will show ISxN 13 format for numbers that do not fit in the short version. The EAN13, ISBN13, ISMN13 and ISSN13 types will always display the long version of the ISxN (EAN13).

F.19.2. Casts

The isn module provides the following pairs of type casts:

- ISBN13 <=> EAN13
- ISMN13 <=> EAN13
- ISSN13 <=> EAN13
- ISBN <=> EAN13
- ISMN <=> EAN13
- ISSN <=> EAN13
- UPC <=> EAN13
- ISBN <=> ISBN13
- ISMN <=> ISMN13
- ISSN <=> ISSN13

When casting from EAN13 to another type, there is a run-time check that the value is within the domain of the other type, and an error is thrown if not. The other casts are simply relabelings that will always succeed.

F.19.3. Functions and Operators

The isn module provides the standard comparison operators, plus B-tree and hash indexing support for all these data types. In addition there are several specialized functions; shown in Table F-11. In this table, isn means any one of the module's data types.

Table F-11. isn Functions

Function	Returns	Description
isn_weak(boolean)	boolean	Sets the weak input mode (returns new setting)
isn_weak()	boolean	Gets the current status of the weak mode
make_valid(isn)	isn	Validates an invalid number (clears the invalid flag)
is_valid(isn)	boolean	Checks for the presence of the invalid flag

Weak mode is used to be able to insert invalid data into a table. Invalid means the check digit is wrong, not that there are missing numbers.

Why would you want to use the weak mode? Well, it could be that you have a huge collection of ISBN numbers, and that there are so many of them that for weird reasons some have the wrong check digit (perhaps the numbers were scanned from a printed list and the OCR got the numbers wrong,

perhaps the numbers were manually captured... who knows). Anyway, the point is you might want to clean the mess up, but you still want to be able to have all the numbers in your database and maybe use an external tool to locate the invalid numbers in the database so you can verify the information and validate it more easily; so for example you'd want to select all the invalid numbers in the table.

When you insert invalid numbers in a table using the weak mode, the number will be inserted with the corrected check digit, but it will be displayed with an exclamation mark (`!`) at the end, for example `0-11-000322-5!`. This invalid marker can be checked with the `is_valid` function and cleared with the `make_valid` function.

You can also force the insertion of invalid numbers even when not in the weak mode, by appending the `!` character at the end of the number.

Another special feature is that during input, you can write `?` in place of the check digit, and the correct check digit will be inserted automatically.

F.19.4. Examples

```
--Using the types directly:
SELECT isbn('978-0-393-04002-9');
SELECT isbn13('0901690546');
SELECT issn('1436-4522');

--Casting types:
-- note that you can only cast from ean13 to another type when the
-- number would be valid in the realm of the target type;
-- thus, the following will NOT work: select isbn(ean13('0220356483481'));
-- but these will:
SELECT upc(ean13('0220356483481'));
SELECT ean13(upc('220356483481'));

--Create a table with a single column to hold ISBN numbers:
CREATE TABLE test (id isbn);
INSERT INTO test VALUES('9780393040029');

--Automatically calculate check digits (observe the '?'):
INSERT INTO test VALUES('220500896?');
INSERT INTO test VALUES('978055215372?');

SELECT issn('3251231?');
SELECT ismn('979047213542?');

--Using the weak mode:
SELECT isn_weak(true);
INSERT INTO test VALUES('978-0-11-000533-4');
INSERT INTO test VALUES('9780141219307');
INSERT INTO test VALUES('2-205-00876-X');
SELECT isn_weak(false);

SELECT id FROM test WHERE NOT is_valid(id);
UPDATE test SET id = make_valid(id) WHERE id = '2-205-00876-X!';

SELECT * FROM test;

SELECT isbn13(id) FROM test;
```

F.19.5. Bibliography

The information to implement this module was collected from several sites, including:

- http://www.isbn-international.org/
- http://www.issn.org/
- http://www.ismn-international.org/
- http://www.wikipedia.org/

The prefixes used for hyphenation were also compiled from:

- http://www.gs1.org/productssolutions/idkeys/support/prefix_list.html
- http://en.wikipedia.org/wiki/List_of_ISBN_identifier_groups
- https://www.isbn-international.org/content/isbn-users-manual
- http://en.wikipedia.org/wiki/International_Standard_Music_Number
- http://www.ismn-international.org/ranges.html

Care was taken during the creation of the algorithms and they were meticulously verified against the suggested algorithms in the official ISBN, ISMN, ISSN User Manuals.

F.19.6. Author

Germán Méndez Bravo (Kronuz), 2004 - 2006

This module was inspired by Garrett A. Wollman's `isbn_issn` code.

F.20. lo

The `lo` module provides support for managing Large Objects (also called LOs or BLOBs). This includes a data type `lo` and a trigger `lo_manage`.

F.20.1. Rationale

One of the problems with the JDBC driver (and this affects the ODBC driver also), is that the specification assumes that references to BLOBs (Binary Large OBjects) are stored within a table, and if that entry is changed, the associated BLOB is deleted from the database.

As PostgreSQL stands, this doesn't occur. Large objects are treated as objects in their own right; a table entry can reference a large object by OID, but there can be multiple table entries referencing the same large object OID, so the system doesn't delete the large object just because you change or remove one such entry.

Now this is fine for PostgreSQL-specific applications, but standard code using JDBC or ODBC won't delete the objects, resulting in orphan objects — objects that are not referenced by anything, and simply occupy disk space.

The `lo` module allows fixing this by attaching a trigger to tables that contain LO reference columns. The trigger essentially just does a `lo_unlink` whenever you delete or modify a value referencing a

large object. When you use this trigger, you are assuming that there is only one database reference to any large object that is referenced in a trigger-controlled column!

The module also provides a data type `lo`, which is really just a domain of the `oid` type. This is useful for differentiating database columns that hold large object references from those that are OIDs of other things. You don't have to use the `lo` type to use the trigger, but it may be convenient to use it to keep track of which columns in your database represent large objects that you are managing with the trigger. It is also rumored that the ODBC driver gets confused if you don't use `lo` for BLOB columns.

F.20.2. How to Use It

Here's a simple example of usage:

```
CREATE TABLE image (title TEXT, raster lo);

CREATE TRIGGER t_raster BEFORE UPDATE OR DELETE ON image
    FOR EACH ROW EXECUTE PROCEDURE lo_manage(raster);
```

For each column that will contain unique references to large objects, create a `BEFORE UPDATE OR DELETE` trigger, and give the column name as the sole trigger argument. You can also restrict the trigger to only execute on updates to the column by using `BEFORE UPDATE OF` *`column_name`*. If you need multiple `lo` columns in the same table, create a separate trigger for each one, remembering to give a different name to each trigger on the same table.

F.20.3. Limitations

- Dropping a table will still orphan any objects it contains, as the trigger is not executed. You can avoid this by preceding the `DROP TABLE` with `DELETE FROM` *`table`*.

  `TRUNCATE` has the same hazard.

  If you already have, or suspect you have, orphaned large objects, see the vacuumlo module to help you clean them up. It's a good idea to run vacuumlo occasionally as a back-stop to the `lo_manage` trigger.
- Some frontends may create their own tables, and will not create the associated trigger(s). Also, users may not remember (or know) to create the triggers.

F.20.4. Author

Peter Mount <peter@retep.org.uk>

F.21. ltree

This module implements a data type `ltree` for representing labels of data stored in a hierarchical tree-like structure. Extensive facilities for searching through label trees are provided.

F.21.1. Definitions

A *label* is a sequence of alphanumeric characters and underscores (for example, in C locale the characters `A-Za-z0-9_` are allowed). Labels must be less than 256 bytes long.

Examples: `42`, `Personal_Services`

A *label path* is a sequence of zero or more labels separated by dots, for example `L1.L2.L3`, representing a path from the root of a hierarchical tree to a particular node. The length of a label path must be less than 65Kb, but keeping it under 2Kb is preferable. In practice this is not a major limitation; for example, the longest label path in the DMOZ catalog (http://www.dmoz.org) is about 240 bytes.

Example: `Top.Countries.Europe.Russia`

The `ltree` module provides several data types:

- `ltree` stores a label path.
- `lquery` represents a regular-expression-like pattern for matching `ltree` values. A simple word matches that label within a path. A star symbol (`*`) matches zero or more labels. For example:

  ```
  foo         Match the exact label path foo
  *.foo.*     Match any label path containing the label foo
  *.foo       Match any label path whose last label is foo
  ```

  Star symbols can also be quantified to restrict how many labels they can match:

  ```
  *{n}        Match exactly n labels
  *{n,}       Match at least n labels
  *{n,m}      Match at least n but not more than m labels
  *{,m}       Match at most m labels -- same as  *{0,m}
  ```

  There are several modifiers that can be put at the end of a non-star label in `lquery` to make it match more than just the exact match:

  ```
  @           Match case-insensitively, for example a@ matches A
  *           Match any label with this prefix, for example foo* matches foobar
  %           Match initial underscore-separated words
  ```

  The behavior of `%` is a bit complicated. It tries to match words rather than the entire label. For example `foo_bar%` matches `foo_bar_baz` but not `foo_barbaz`. If combined with `*`, prefix matching applies to each word separately, for example `foo_bar%*` matches `foo1_bar2_baz` but not `foo1_br2_baz`.

  Also, you can write several possibly-modified labels separated with `|` (OR) to match any of those labels, and you can put `!` (NOT) at the start to match any label that doesn't match any of the alternatives.

  Here's an annotated example of `lquery`:

  ```
  Top.*{0,2}.sport*@.!football|tennis.Russ*|Spain
  a.  b.     c.      d.               e.
  ```

  This query will match any label path that:

  a. begins with the label `Top`

  b. and next has zero to two labels before

  c. a label beginning with the case-insensitive prefix `sport`

  d. then a label not matching `football` nor `tennis`

  e. and then ends with a label beginning with `Russ` or exactly matching `Spain`.

- `ltxtquery` represents a full-text-search-like pattern for matching `ltree` values. An `ltxtquery` value contains words, possibly with the modifiers `@`, `*`, `%` at the end; the modifiers have the same meanings as in `lquery`. Words can be combined with `&` (AND), `|` (OR), `!` (NOT), and parentheses. The key difference from `lquery` is that `ltxtquery` matches words without regard to their position in the label path.

  Here's an example `ltxtquery`:

  ```
  Europe & Russia*@ & !Transportation
  ```

  This will match paths that contain the label `Europe` and any label beginning with `Russia` (case-insensitive), but not paths containing the label `Transportation`. The location of these words within the path is not important. Also, when `%` is used, the word can be matched to any underscore-separated word within a label, regardless of position.

Note: `ltxtquery` allows whitespace between symbols, but `ltree` and `lquery` do not.

F.21.2. Operators and Functions

Type `ltree` has the usual comparison operators =, <>, <, >, <=, >=. Comparison sorts in the order of a tree traversal, with the children of a node sorted by label text. In addition, the specialized operators shown in Table F-12 are available.

Table F-12. `ltree` Operators

Operator	Returns	Description
`ltree @> ltree`	`boolean`	is left argument an ancestor of right (or equal)?
`ltree <@ ltree`	`boolean`	is left argument a descendant of right (or equal)?
`ltree ~ lquery`	`boolean`	does `ltree` match `lquery`?
`lquery ~ ltree`	`boolean`	does `ltree` match `lquery`?
`ltree ? lquery[]`	`boolean`	does `ltree` match any `lquery` in array?
`lquery[] ? ltree`	`boolean`	does `ltree` match any `lquery` in array?
`ltree @ ltxtquery`	`boolean`	does `ltree` match `ltxtquery`?
`ltxtquery @ ltree`	`boolean`	does `ltree` match `ltxtquery`?
`ltree || ltree`	`ltree`	concatenate `ltree` paths
`ltree || text`	`ltree`	convert text to `ltree` and concatenate
`text || ltree`	`ltree`	convert text to `ltree` and concatenate
`ltree[] @> ltree`	`boolean`	does array contain an ancestor of `ltree`?
`ltree <@ ltree[]`	`boolean`	does array contain an ancestor of `ltree`?

Operator	Returns	Description
`ltree[] <@ ltree`	`boolean`	does array contain a descendant of `ltree`?
`ltree @> ltree[]`	`boolean`	does array contain a descendant of `ltree`?
`ltree[] ~ lquery`	`boolean`	does array contain any path matching `lquery`?
`lquery ~ ltree[]`	`boolean`	does array contain any path matching `lquery`?
`ltree[] ? lquery[]`	`boolean`	does `ltree` array contain any path matching any `lquery`?
`lquery[] ? ltree[]`	`boolean`	does `ltree` array contain any path matching any `lquery`?
`ltree[] @ ltxtquery`	`boolean`	does array contain any path matching `ltxtquery`?
`ltxtquery @ ltree[]`	`boolean`	does array contain any path matching `ltxtquery`?
`ltree[] ?@> ltree`	`ltree`	first array entry that is an ancestor of `ltree`; NULL if none
`ltree[] ?<@ ltree`	`ltree`	first array entry that is a descendant of `ltree`; NULL if none
`ltree[] ?~ lquery`	`ltree`	first array entry that matches `lquery`; NULL if none
`ltree[] ?@ ltxtquery`	`ltree`	first array entry that matches `ltxtquery`; NULL if none

The operators `<@`, `@>`, `@` and `~` have analogues `^<@`, `^@>`, `^@`, `^~`, which are the same except they do not use indexes. These are useful only for testing purposes.

The available functions are shown in Table F-13.

Table F-13. `ltree` Functions

Function	Return Type	Description	Example	Result
`subltree(ltree, int start, int end)`	`ltree`	subpath of `ltree` from position `start` to position `end`-1 (counting from 0)	`subltree('Top.Child1.Child2',1,2)`	`Child1`

Function	Return Type	Description	Example	Result
`subpath(ltree, int offset, int len)`	`ltree`	subpath of `ltree` starting at position `offset`, length `len`. If `offset` is negative, subpath starts that far from the end of the path. If `len` is negative, leaves that many labels off the end of the path.	`subpath('Top.Child1.Child2',0,2)`	`Top.Child1`
`subpath(ltree, int offset)`	`ltree`	subpath of `ltree` starting at position `offset`, extending to end of path. If `offset` is negative, subpath starts that far from the end of the path.	`subpath('Top.Child1.Child2',1)`	`Child1.Child2`
`nlevel(ltree)`	`integer`	number of labels in path	`nlevel('Top.Child1.Child2')`	`3`
`index(ltree a, ltree b)`	`integer`	position of first occurrence of `b` in `a`; -1 if not found	`index('0.1.2.3.5.4.5.6.8.5.6.8','5.6')`	
`index(ltree a, ltree b, int offset)`	`integer`	position of first occurrence of `b` in `a`, searching starting at `offset`; negative `offset` means start `-offset` labels from the end of the path	`index('0.1.2.3.5.4.5.6.8.5.6.8','5.6',-4)`	
`text2ltree(text)`	`ltree`	cast `text` to `ltree`		
`ltree2text(ltree)`	`text`	cast `ltree` to `text`		
`lca(ltree, ltree, ...)`	`ltree`	lowest common ancestor, i.e., longest common prefix of paths (up to 8 arguments supported)	`lca('1.2.2.3','1.2.3.4.5.6')`	

Function	Return Type	Description	Example	Result
`lca(ltree[])`	`ltree`	lowest common ancestor, i.e., longest common prefix of paths	`lca(array['1.2.2.3'::ltree,'1.2.3'])`	

F.21.3. Indexes

`ltree` supports several types of indexes that can speed up the indicated operators:

- B-tree index over `ltree`: <, <=, =, >=, >
- GiST index over `ltree`: <, <=, =, >=, >, @>, <@, @, ~, ?

  Example of creating such an index:

  ```
  CREATE INDEX path_gist_idx ON test USING GIST (path);
  ```

- GiST index over `ltree[]`: `ltree[] <@ ltree`, `ltree @> ltree[]`, @, ~, ?

  Example of creating such an index:

  ```
  CREATE INDEX path_gist_idx ON test USING GIST (array_path);
  ```

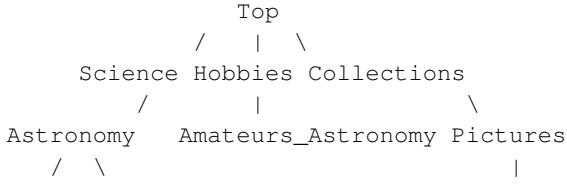
  Note: This index type is lossy.

F.21.4. Example

This example uses the following data (also available in file `contrib/ltree/ltreetest.sql` in the source distribution):

```
CREATE TABLE test (path ltree);
INSERT INTO test VALUES ('Top');
INSERT INTO test VALUES ('Top.Science');
INSERT INTO test VALUES ('Top.Science.Astronomy');
INSERT INTO test VALUES ('Top.Science.Astronomy.Astrophysics');
INSERT INTO test VALUES ('Top.Science.Astronomy.Cosmology');
INSERT INTO test VALUES ('Top.Hobbies');
INSERT INTO test VALUES ('Top.Hobbies.Amateurs_Astronomy');
INSERT INTO test VALUES ('Top.Collections');
INSERT INTO test VALUES ('Top.Collections.Pictures');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy.Stars');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy.Galaxies');
INSERT INTO test VALUES ('Top.Collections.Pictures.Astronomy.Astronauts');
CREATE INDEX path_gist_idx ON test USING gist(path);
CREATE INDEX path_idx ON test USING btree(path);
```

Now, we have a table `test` populated with data describing the hierarchy shown below:



```
Astrophysics  Cosmology                Astronomy
                                        /  |    \
                                  Galaxies Stars Astronauts
```

We can do inheritance:

```
ltreetest=> SELECT path FROM test WHERE path <@ 'Top.Science';
                path
-----------------------------------
 Top.Science
 Top.Science.Astronomy
 Top.Science.Astronomy.Astrophysics
 Top.Science.Astronomy.Cosmology
(4 rows)
```

Here are some examples of path matching:

```
ltreetest=> SELECT path FROM test WHERE path ~ '*.Astronomy.*';
                      path
-----------------------------------------------
 Top.Science.Astronomy
 Top.Science.Astronomy.Astrophysics
 Top.Science.Astronomy.Cosmology
 Top.Collections.Pictures.Astronomy
 Top.Collections.Pictures.Astronomy.Stars
 Top.Collections.Pictures.Astronomy.Galaxies
 Top.Collections.Pictures.Astronomy.Astronauts
(7 rows)

ltreetest=> SELECT path FROM test WHERE path ~ '*.!pictures@.*.Astronomy.*';
                path
-----------------------------------
 Top.Science.Astronomy
 Top.Science.Astronomy.Astrophysics
 Top.Science.Astronomy.Cosmology
(3 rows)
```

Here are some examples of full text search:

```
ltreetest=> SELECT path FROM test WHERE path @ 'Astro*% & !pictures@';
                path
-----------------------------------
 Top.Science.Astronomy
 Top.Science.Astronomy.Astrophysics
 Top.Science.Astronomy.Cosmology
 Top.Hobbies.Amateurs_Astronomy
(4 rows)

ltreetest=> SELECT path FROM test WHERE path @ 'Astro* & !pictures@';
                path
-----------------------------------
 Top.Science.Astronomy
 Top.Science.Astronomy.Astrophysics
 Top.Science.Astronomy.Cosmology
(3 rows)
```

Path construction using functions:

```
ltreetest=> SELECT subpath(path,0,2)||'Space'||subpath(path,2) FROM test WHERE path <@ '
                ?column?
----------------------------------------
 Top.Science.Space.Astronomy
 Top.Science.Space.Astronomy.Astrophysics
 Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

We could simplify this by creating a SQL function that inserts a label at a specified position in a path:

```
CREATE FUNCTION ins_label(ltree, int, text) RETURNS ltree
    AS 'select subpath($1,0,$2) || $3 || subpath($1,$2);'
    LANGUAGE SQL IMMUTABLE;

ltreetest=> SELECT ins_label(path,2,'Space') FROM test WHERE path <@ 'Top.Science.Astron
                ins_label
----------------------------------------
 Top.Science.Space.Astronomy
 Top.Science.Space.Astronomy.Astrophysics
 Top.Science.Space.Astronomy.Cosmology
(3 rows)
```

F.21.5. Authors

All work was done by Teodor Sigaev (<teodor@stack.net>) and Oleg Bartunov (<oleg@sai.msu.su>). See http://www.sai.msu.su/~megera/postgres/gist/ for additional information. Authors would like to thank Eugeny Rodichev for helpful discussions. Comments and bug reports are welcome.

F.22. pageinspect

The pageinspect module provides functions that allow you to inspect the contents of database pages at a low level, which is useful for debugging purposes. All of these functions may be used only by superusers.

F.22.1. Functions

`get_raw_page(relname text, fork text, blkno int) returns bytea`

get_raw_page reads the specified block of the named relation and returns a copy as a bytea value. This allows a single time-consistent copy of the block to be obtained. *fork* should be 'main' for the main data fork, 'fsm' for the free space map, 'vm' for the visibility map, or 'init' for the initialization fork.

`get_raw_page(relname text, blkno int) returns bytea`

A shorthand version of `get_raw_page`, for reading from the main fork. Equivalent to `get_raw_page(relname, 'main', blkno)`

`page_header(page bytea) returns record`

`page_header` shows fields that are common to all PostgreSQL heap and index pages.

A page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM page_header(get_raw_page('pg_class', 0));
    lsn    | checksum | flags  | lower | upper | special | pagesize | version | prune
-----------+----------+--------+-------+-------+---------+----------+---------+------
 0/24A1B50 |        1 |      1 |   232 |   368 |    8192 |     8192 |       4 |
```

The returned columns correspond to the fields in the `PageHeaderData` struct. See `src/include/storage/bufpage.h` for details.

`heap_page_items(page bytea) returns setof record`

`heap_page_items` shows all line pointers on a heap page. For those line pointers that are in use, tuple headers are also shown. All tuples are shown, whether or not the tuples were visible to an MVCC snapshot at the time the raw page was copied.

A heap page image obtained with `get_raw_page` should be passed as argument. For example:

```
test=# SELECT * FROM heap_page_items(get_raw_page('pg_class', 0));
```

See `src/include/storage/itemid.h` and `src/include/access/htup_details.h` for explanations of the fields returned.

`bt_metap(relname text) returns record`

`bt_metap` returns information about a B-tree index's metapage. For example:

```
test=# SELECT * FROM bt_metap('pg_cast_oid_index');
-[ RECORD 1 ]-----
magic     | 340322
version   | 2
root      | 1
level     | 0
fastroot  | 1
fastlevel | 0
```

`bt_page_stats(relname text, blkno int) returns record`

`bt_page_stats` returns summary information about single pages of B-tree indexes. For example:

```
test=# SELECT * FROM bt_page_stats('pg_cast_oid_index', 1);
-[ RECORD 1 ]-+-----
blkno         | 1
type          | l
live_items    | 256
dead_items    | 0
avg_item_size | 12
page_size     | 8192
free_size     | 4056
btpo_prev     | 0
btpo_next     | 0
btpo          | 0
btpo_flags    | 3
```

```
bt_page_items(relname text, blkno int) returns setof record
```

`bt_page_items` returns detailed information about all of the items on a B-tree index page. For example:

```
test=# SELECT * FROM bt_page_items('pg_cast_oid_index', 1);
 itemoffset |  ctid   | itemlen | nulls | vars |    data
------------+---------+---------+-------+------+-------------
          1 | (0,1)   |      12 | f     | f    | 23 27 00 00
          2 | (0,2)   |      12 | f     | f    | 24 27 00 00
          3 | (0,3)   |      12 | f     | f    | 25 27 00 00
          4 | (0,4)   |      12 | f     | f    | 26 27 00 00
          5 | (0,5)   |      12 | f     | f    | 27 27 00 00
          6 | (0,6)   |      12 | f     | f    | 28 27 00 00
          7 | (0,7)   |      12 | f     | f    | 29 27 00 00
          8 | (0,8)   |      12 | f     | f    | 2a 27 00 00
```

```
fsm_page_contents(page bytea) returns text
```

`fsm_page_contents` shows the internal node structure of a FSM page. The output is a multiline string, with one line per node in the binary tree within the page. Only those nodes that are not zero are printed. The so-called "next" pointer, which points to the next slot to be returned from the page, is also printed.

See `src/backend/storage/freespace/README` for more information on the structure of an FSM page.

F.23. passwordcheck

The `passwordcheck` module checks users' passwords whenever they are set with CREATE ROLE or ALTER ROLE. If a password is considered too weak, it will be rejected and the command will terminate with an error.

To enable this module, add `'$libdir/passwordcheck'` to shared_preload_libraries in `postgresql.conf`, then restart the server.

You can adapt this module to your needs by changing the source code. For example, you can use CrackLib[2] to check passwords — this only requires uncommenting two lines in the `Makefile` and rebuilding the module. (We cannot include CrackLib by default for license reasons.) Without CrackLib, the module enforces a few simple rules for password strength, which you can modify or extend as you see fit.

2. http://sourceforge.net/projects/cracklib/

Caution

To prevent unencrypted passwords from being sent across the network, written to the server log or otherwise stolen by a database administrator, PostgreSQL allows the user to supply pre-encrypted passwords. Many client programs make use of this functionality and encrypt the password before sending it to the server.

This limits the usefulness of the `passwordcheck` module, because in that case it can only try to guess the password. For this reason, `passwordcheck` is not recommended if your security requirements are high. It is more secure to use an external authentication method such as GSSAPI (see Chapter 19) than to rely on passwords within the database.

Alternatively, you could modify `passwordcheck` to reject pre-encrypted passwords, but forcing users to set their passwords in clear text carries its own security risks.

F.24. pg_buffercache

The `pg_buffercache` module provides a means for examining what's happening in the shared buffer cache in real time.

The module provides a C function `pg_buffercache_pages` that returns a set of records, plus a view `pg_buffercache` that wraps the function for convenient use.

By default public access is revoked from both of these, just in case there are security issues lurking.

F.24.1. The `pg_buffercache` View

The definitions of the columns exposed by the view are shown in Table F-14.

Table F-14. `pg_buffercache` Columns

Name	Type	References	Description
`bufferid`	`integer`		ID, in the range 1..`shared_buffers`
`relfilenode`	`oid`	`pg_class.relfilenode`	Filenode number of the relation
`reltablespace`	`oid`	`pg_tablespace.oid`	Tablespace OID of the relation
`reldatabase`	`oid`	`pg_database.oid`	Database OID of the relation
`relforknumber`	`smallint`		Fork number within the relation; see `include/storage/relfilenode.h`
`relblocknumber`	`bigint`		Page number within the relation
`isdirty`	`boolean`		Is the page dirty?

Name	Type	References	Description
usagecount	smallint		Clock-sweep access count

There is one row for each buffer in the shared cache. Unused buffers are shown with all fields null except bufferid. Shared system catalogs are shown as belonging to database zero.

Because the cache is shared by all the databases, there will normally be pages from relations not belonging to the current database. This means that there may not be matching join rows in pg_class for some rows, or that there could even be incorrect joins. If you are trying to join against pg_class, it's a good idea to restrict the join to rows having reldatabase equal to the current database's OID or zero.

When the pg_buffercache view is accessed, internal buffer manager locks are taken for long enough to copy all the buffer state data that the view will display. This ensures that the view produces a consistent set of results, while not blocking normal buffer activity longer than necessary. Nonetheless there could be some impact on database performance if this view is read often.

F.24.2. Sample Output

```
regression=# SELECT c.relname, count(*) AS buffers
             FROM pg_buffercache b INNER JOIN pg_class c
             ON b.relfilenode = pg_relation_filenode(c.oid) AND
                b.reldatabase IN (0, (SELECT oid FROM pg_database
                                      WHERE datname = current_database()))
             GROUP BY c.relname
             ORDER BY 2 DESC
             LIMIT 10;

              relname             | buffers
----------------------------------+---------
 tenk2                            |     345
 tenk1                            |     141
 pg_proc                          |      46
 pg_class                         |      45
 pg_attribute                     |      43
 pg_class_relname_nsp_index       |      30
 pg_proc_proname_args_nsp_index   |      28
 pg_attribute_relid_attnam_index  |      26
 pg_depend                        |      22
 pg_depend_reference_index        |      20
(10 rows)
```

F.24.3. Authors

Mark Kirkwood <markir@paradise.net.nz>

Design suggestions: Neil Conway <neilc@samurai.com>

Debugging advice: Tom Lane <tgl@sss.pgh.pa.us>

F.25. pgcrypto

The pgcrypto module provides cryptographic functions for PostgreSQL.

F.25.1. General Hashing Functions

F.25.1.1. digest()

```
digest(data text, type text) returns bytea
digest(data bytea, type text) returns bytea
```

Computes a binary hash of the given data. type is the algorithm to use. Standard algorithms are md5, sha1, sha224, sha256, sha384 and sha512. If pgcrypto was built with OpenSSL, more algorithms are available, as detailed in Table F-18.

If you want the digest as a hexadecimal string, use encode() on the result. For example:

```
CREATE OR REPLACE FUNCTION sha1(bytea) returns text AS $$
    SELECT encode(digest($1, 'sha1'), 'hex')
$$ LANGUAGE SQL STRICT IMMUTABLE;
```

F.25.1.2. hmac()

```
hmac(data text, key text, type text) returns bytea
hmac(data bytea, key text, type text) returns bytea
```

Calculates hashed MAC for data with key key. type is the same as in digest().

This is similar to digest() but the hash can only be recalculated knowing the key. This prevents the scenario of someone altering data and also changing the hash to match.

If the key is larger than the hash block size it will first be hashed and the result will be used as key.

F.25.2. Password Hashing Functions

The functions crypt() and gen_salt() are specifically designed for hashing passwords. crypt() does the hashing and gen_salt() prepares algorithm parameters for it.

The algorithms in crypt() differ from the usual MD5 or SHA1 hashing algorithms in the following respects:

1. They are slow. As the amount of data is so small, this is the only way to make brute-forcing passwords hard.
2. They use a random value, called the *salt*, so that users having the same password will have different encrypted passwords. This is also an additional defense against reversing the algorithm.
3. They include the algorithm type in the result, so passwords hashed with different algorithms can co-exist.

4. Some of them are adaptive — that means when computers get faster, you can tune the algorithm to be slower, without introducing incompatibility with existing passwords.

Table F-15 lists the algorithms supported by the `crypt()` function.

Table F-15. Supported Algorithms for `crypt()`

Algorithm	Max Password Length	Adaptive?	Salt Bits	Output Length	Description
`bf`	72	yes	128	60	Blowfish-based, variant 2a
`md5`	unlimited	no	48	34	MD5-based crypt
`xdes`	8	yes	24	20	Extended DES
`des`	8	no	12	13	Original UNIX crypt

F.25.2.1. `crypt()`

```
crypt(password text, salt text) returns text
```

Calculates a crypt(3)-style hash of `password`. When storing a new password, you need to use `gen_salt()` to generate a new `salt` value. To check a password, pass the stored hash value as `salt`, and test whether the result matches the stored value.

Example of setting a new password:

```
UPDATE ... SET pswhash = crypt('new password', gen_salt('md5'));
```

Example of authentication:

```
SELECT (pswhash = crypt('entered password', pswhash)) AS pswmatch FROM ... ;
```

This returns `true` if the entered password is correct.

F.25.2.2. `gen_salt()`

```
gen_salt(type text [, iter_count integer ]) returns text
```

Generates a new random salt string for use in `crypt()`. The salt string also tells `crypt()` which algorithm to use.

The `type` parameter specifies the hashing algorithm. The accepted types are: `des`, `xdes`, `md5` and `bf`.

The `iter_count` parameter lets the user specify the iteration count, for algorithms that have one. The higher the count, the more time it takes to hash the password and therefore the more time to break it. Although with too high a count the time to calculate a hash may be several years — which is somewhat impractical. If the `iter_count` parameter is omitted, the default iteration count is used. Allowed values for `iter_count` depend on the algorithm and are shown in Table F-16.

Table F-16. Iteration Counts for `crypt()`

Algorithm	Default	Min	Max
`xdes`	725	1	16777215
`bf`	6	4	31

For `xdes` there is an additional limitation that the iteration count must be an odd number.

To pick an appropriate iteration count, consider that the original DES crypt was designed to have the speed of 4 hashes per second on the hardware of that time. Slower than 4 hashes per second would probably dampen usability. Faster than 100 hashes per second is probably too fast.

Table F-17 gives an overview of the relative slowness of different hashing algorithms. The table shows how much time it would take to try all combinations of characters in an 8-character password, assuming that the password contains either only lower case letters, or upper- and lower-case letters and numbers. In the `crypt-bf` entries, the number after a slash is the `iter_count` parameter of `gen_salt`.

Table F-17. Hash Algorithm Speeds

Algorithm	Hashes/sec	For `[a-z]`	For `[A-Za-z0-9]`	Duration relative to `md5 hash`
`crypt-bf/8`	1792	4 years	3927 years	100k
`crypt-bf/7`	3648	2 years	1929 years	50k
`crypt-bf/6`	7168	1 year	982 years	25k
`crypt-bf/5`	13504	188 days	521 years	12.5k
`crypt-md5`	171584	15 days	41 years	1k
`crypt-des`	23221568	157.5 minutes	108 days	7
`sha1`	37774272	90 minutes	68 days	4
`md5` (hash)	150085504	22.5 minutes	17 days	1

Notes:

- The machine used is an Intel Mobile Core i3.
- `crypt-des` and `crypt-md5` algorithm numbers are taken from John the Ripper v1.6.38 `-test` output.
- `md5 hash` numbers are from mdcrack 1.2.
- `sha1` numbers are from lcrack-20031130-beta.
- `crypt-bf` numbers are taken using a simple program that loops over 1000 8-character passwords. That way I can show the speed with different numbers of iterations. For reference: `john -test` shows 213 loops/sec for `crypt-bf/5`. (The very small difference in results is in accordance with the fact that the `crypt-bf` implementation in `pgcrypto` is the same one used in John the Ripper.)

Note that “try all combinations” is not a realistic exercise. Usually password cracking is done with the help of dictionaries, which contain both regular words and various mutations of them. So, even somewhat word-like passwords could be cracked much faster than the above numbers suggest, while a 6-character non-word-like password may escape cracking. Or not.

F.25.3. PGP Encryption Functions

The functions here implement the encryption part of the OpenPGP (RFC 4880) standard. Supported are both symmetric-key and public-key encryption.

An encrypted PGP message consists of 2 parts, or *packets*:

- Packet containing a session key — either symmetric-key or public-key encrypted.
- Packet containing data encrypted with the session key.

When encrypting with a symmetric key (i.e., a password):

1. The given password is hashed using a String2Key (S2K) algorithm. This is rather similar to `crypt()` algorithms — purposefully slow and with random salt — but it produces a full-length binary key.
2. If a separate session key is requested, a new random key will be generated. Otherwise the S2K key will be used directly as the session key.
3. If the S2K key is to be used directly, then only S2K settings will be put into the session key packet. Otherwise the session key will be encrypted with the S2K key and put into the session key packet.

When encrypting with a public key:

1. A new random session key is generated.
2. It is encrypted using the public key and put into the session key packet.

In either case the data to be encrypted is processed as follows:

1. Optional data-manipulation: compression, conversion to UTF-8, and/or conversion of line-endings.
2. The data is prefixed with a block of random bytes. This is equivalent to using a random IV.
3. An SHA1 hash of the random prefix and data is appended.
4. All this is encrypted with the session key and placed in the data packet.

F.25.3.1. `pgp_sym_encrypt()`

```
pgp_sym_encrypt(data text, psw text [, options text ]) returns bytea
pgp_sym_encrypt_bytea(data bytea, psw text [, options text ]) returns bytea
```

Encrypt `data` with a symmetric PGP key `psw`. The `options` parameter can contain option settings, as described below.

F.25.3.2. `pgp_sym_decrypt()`

```
pgp_sym_decrypt(msg bytea, psw text [, options text ]) returns text
pgp_sym_decrypt_bytea(msg bytea, psw text [, options text ]) returns bytea
```

Decrypt a symmetric-key-encrypted PGP message.

Decrypting `bytea` data with `pgp_sym_decrypt` is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with `pgp_sym_decrypt_bytea` is fine.

The options parameter can contain option settings, as described below.

F.25.3.3. pgp_pub_encrypt()

```
pgp_pub_encrypt(data text, key bytea [, options text ]) returns bytea
pgp_pub_encrypt_bytea(data bytea, key bytea [, options text ]) returns bytea
```

Encrypt data with a public PGP key key. Giving this function a secret key will produce an error.

The options parameter can contain option settings, as described below.

F.25.3.4. pgp_pub_decrypt()

```
pgp_pub_decrypt(msg bytea, key bytea [, psw text [, options text ]]) returns text
pgp_pub_decrypt_bytea(msg bytea, key bytea [, psw text [, options text ]]) returns bytea
```

Decrypt a public-key-encrypted message. key must be the secret key corresponding to the public key that was used to encrypt. If the secret key is password-protected, you must give the password in psw. If there is no password, but you want to specify options, you need to give an empty password.

Decrypting bytea data with pgp_pub_decrypt is disallowed. This is to avoid outputting invalid character data. Decrypting originally textual data with pgp_pub_decrypt_bytea is fine.

The options parameter can contain option settings, as described below.

F.25.3.5. pgp_key_id()

```
pgp_key_id(bytea) returns text
```

pgp_key_id extracts the key ID of a PGP public or secret key. Or it gives the key ID that was used for encrypting the data, if given an encrypted message.

It can return 2 special key IDs:

- SYMKEY

  The message is encrypted with a symmetric key.

- ANYKEY

  The message is public-key encrypted, but the key ID has been removed. That means you will need to try all your secret keys on it to see which one decrypts it. pgcrypto itself does not produce such messages.

Note that different keys may have the same ID. This is rare but a normal event. The client application should then try to decrypt with each one, to see which fits — like handling ANYKEY.

F.25.3.6. armor(), dearmor()

```
armor(data bytea) returns text
dearmor(data text) returns bytea
```

These functions wrap/unwrap binary data into PGP ASCII-armor format, which is basically Base64 with CRC and additional formatting.

F.25.3.7. Options for PGP Functions

Options are named to be similar to GnuPG. An option's value should be given after an equal sign; separate options from each other with commas. For example:

```
pgp_sym_encrypt(data, psw, 'compress-algo=1, cipher-algo=aes256')
```

All of the options except `convert-crlf` apply only to encrypt functions. Decrypt functions get the parameters from the PGP data.

The most interesting options are probably `compress-algo` and `unicode-mode`. The rest should have reasonable defaults.

F.25.3.7.1. cipher-algo

Which cipher algorithm to use.

Values: bf, aes128, aes192, aes256 (OpenSSL-only: `3des`, `cast5`)
Default: aes128
Applies to: pgp_sym_encrypt, pgp_pub_encrypt

F.25.3.7.2. compress-algo

Which compression algorithm to use. Only available if PostgreSQL was built with zlib.

Values:
0 - no compression
1 - ZIP compression
2 - ZLIB compression (= ZIP plus meta-data and block CRCs)
Default: 0
Applies to: pgp_sym_encrypt, pgp_pub_encrypt

F.25.3.7.3. compress-level

How much to compress. Higher levels compress smaller but are slower. 0 disables compression.

Values: 0, 1-9
Default: 6
Applies to: pgp_sym_encrypt, pgp_pub_encrypt

F.25.3.7.4. convert-crlf

Whether to convert `\n` into `\r\n` when encrypting and `\r\n` to `\n` when decrypting. RFC 4880 specifies that text data should be stored using `\r\n` line-feeds. Use this to get fully RFC-compliant behavior.

Values: 0, 1
Default: 0
Applies to: pgp_sym_encrypt, pgp_pub_encrypt, pgp_sym_decrypt, pgp_pub_decrypt

F.25.3.7.5. disable-mdc

Do not protect data with SHA-1. The only good reason to use this option is to achieve compatibility with ancient PGP products, predating the addition of SHA-1 protected packets to RFC 4880. Recent gnupg.org and pgp.com software supports it fine.

Values: 0, 1
Default: 0
Applies to: pgp_sym_encrypt, pgp_pub_encrypt

F.25.3.7.6. sess-key

Use separate session key. Public-key encryption always uses a separate session key; this option is for symmetric-key encryption, which by default uses the S2K key directly.

Values: 0, 1
Default: 0
Applies to: pgp_sym_encrypt

F.25.3.7.7. s2k-mode

Which S2K algorithm to use.

Values:
 0 - Without salt. Dangerous!
 1 - With salt but with fixed iteration count.
 3 - Variable iteration count.
Default: 3
Applies to: pgp_sym_encrypt

F.25.3.7.8. s2k-digest-algo

Which digest algorithm to use in S2K calculation.

Values: md5, sha1
Default: sha1
Applies to: pgp_sym_encrypt

F.25.3.7.9. s2k-cipher-algo

Which cipher to use for encrypting separate session key.

Values: bf, aes, aes128, aes192, aes256
Default: use cipher-algo
Applies to: pgp_sym_encrypt

F.25.3.7.10. unicode-mode

Whether to convert textual data from database internal encoding to UTF-8 and back. If your database already is UTF-8, no conversion will be done, but the message will be tagged as UTF-8. Without this option it will not be.

Values: 0, 1
Default: 0
Applies to: pgp_sym_encrypt, pgp_pub_encrypt

F.25.3.8. Generating PGP Keys with GnuPG

To generate a new key:

```
gpg --gen-key
```

The preferred key type is "DSA and Elgamal".

For RSA encryption you must create either DSA or RSA sign-only key as master and then add an RSA encryption subkey with `gpg --edit-key`.

To list keys:

```
gpg --list-secret-keys
```

To export a public key in ASCII-armor format:

```
gpg -a --export KEYID > public.key
```

To export a secret key in ASCII-armor format:

```
gpg -a --export-secret-keys KEYID > secret.key
```

You need to use `dearmor()` on these keys before giving them to the PGP functions. Or if you can handle binary data, you can drop `-a` from the command.

For more details see `man gpg`, The GNU Privacy Handbook[3] and other documentation on http://www.gnupg.org.

F.25.3.9. Limitations of PGP Code

- No support for signing. That also means that it is not checked whether the encryption subkey belongs to the master key.
- No support for encryption key as master key. As such practice is generally discouraged, this should not be a problem.

3. http://www.gnupg.org/gph/en/manual.html

- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with `pgcrypto`, but create new ones, as the usage scenario is rather different.

F.25.4. Raw Encryption Functions

These functions only run a cipher over data; they don't have any advanced features of PGP encryption. Therefore they have some major problems:

1. They use user key directly as cipher key.
2. They don't provide any integrity checking, to see if the encrypted data was modified.
3. They expect that users manage all encryption parameters themselves, even IV.
4. They don't handle text.

So, with the introduction of PGP encryption, usage of raw encryption functions is discouraged.

```
encrypt(data bytea, key bytea, type text) returns bytea
decrypt(data bytea, key bytea, type text) returns bytea

encrypt_iv(data bytea, key bytea, iv bytea, type text) returns bytea
decrypt_iv(data bytea, key bytea, iv bytea, type text) returns bytea
```

Encrypt/decrypt data using the cipher method specified by `type`. The syntax of the `type` string is:

```
algorithm [ - mode ] [ /pad: padding ]
```

where *`algorithm`* is one of:

- `bf` — Blowfish
- `aes` — AES (Rijndael-128)

and *`mode`* is one of:

- `cbc` — next block depends on previous (default)
- `ecb` — each block is encrypted separately (for testing only)

and *`padding`* is one of:

- `pkcs` — data may be any length (default)
- `none` — data must be multiple of cipher block size

So, for example, these are equivalent:

```
encrypt(data, 'fooz', 'bf')
encrypt(data, 'fooz', 'bf-cbc/pad:pkcs')
```

In `encrypt_iv` and `decrypt_iv`, the `iv` parameter is the initial value for the CBC mode; it is ignored for ECB. It is clipped or padded with zeroes if not exactly block size. It defaults to all zeroes in the functions without this parameter.

F.25.5. Random-Data Functions

```
gen_random_bytes(count integer) returns bytea
```

Returns `count` cryptographically strong random bytes. At most 1024 bytes can be extracted at a time. This is to avoid draining the randomness generator pool.

```
gen_random_uuid() returns uuid
```

Returns a version 4 (random) UUID.

F.25.6. Notes

F.25.6.1. Configuration

`pgcrypto` configures itself according to the findings of the main PostgreSQL `configure` script. The options that affect it are `--with-zlib` and `--with-openssl`.

When compiled with zlib, PGP encryption functions are able to compress data before encrypting.

When compiled with OpenSSL, there will be more algorithms available. Also public-key encryption functions will be faster as OpenSSL has more optimized BIGNUM functions.

Table F-18. Summary of Functionality with and without OpenSSL

Functionality	Built-in	With OpenSSL
MD5	yes	yes
SHA1	yes	yes
SHA224/256/384/512	yes	yes (Note 1)
Other digest algorithms	no	yes (Note 2)
Blowfish	yes	yes
AES	yes	yes (Note 3)
DES/3DES/CAST5	no	yes
Raw encryption	yes	yes
PGP Symmetric encryption	yes	yes
PGP Public-Key encryption	yes	yes

Notes:

1. SHA2 algorithms were added to OpenSSL in version 0.9.8. For older versions, `pgcrypto` will use built-in code.
2. Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.
3. AES is included in OpenSSL since version 0.9.7. For older versions, `pgcrypto` will use built-in

code.

F.25.6.2. NULL Handling

As is standard in SQL, all functions return NULL, if any of the arguments are NULL. This may create security risks on careless usage.

F.25.6.3. Security Limitations

All `pgcrypto` functions run inside the database server. That means that all the data and passwords move between `pgcrypto` and client applications in clear text. Thus you must:

1. Connect locally or use SSL connections.
2. Trust both system and database administrator.

If you cannot, then better do crypto inside client application.

F.25.6.4. Useful Reading

- http://www.gnupg.org/gph/en/manual.html

  The GNU Privacy Handbook.
- http://www.openwall.com/crypt/

  Describes the crypt-blowfish algorithm.
- http://www.stack.nl/~galactus/remailers/passphrase-faq.html

  How to choose a good password.
- http://world.std.com/~reinhold/diceware.html

  Interesting idea for picking passwords.
- http://www.interhack.net/people/cmcurtin/snake-oil-faq.html

  Describes good and bad cryptography.

F.25.6.5. Technical References

- http://www.ietf.org/rfc/rfc4880.txt

  OpenPGP message format.
- http://www.ietf.org/rfc/rfc1321.txt

  The MD5 Message-Digest Algorithm.
- http://www.ietf.org/rfc/rfc2104.txt

  HMAC: Keyed-Hashing for Message Authentication.
- http://www.usenix.org/events/usenix99/provos.html

  Comparison of crypt-des, crypt-md5 and bcrypt algorithms.
- http://en.wikipedia.org/wiki/Fortuna_(PRNG)

Description of Fortuna CSPRNG.

- http://jlcooke.ca/random/

  Jean-Luc Cooke Fortuna-based `/dev/random` driver for Linux.

- http://research.cyber.ee/~lipmaa/crypto/

  Collection of cryptology pointers.

F.25.7. Author

Marko Kreen <`markokr@gmail.com`>

`pgcrypto` uses code from the following sources:

Algorithm	Author	Source origin
DES crypt	David Burren and others	FreeBSD libcrypt
MD5 crypt	Poul-Henning Kamp	FreeBSD libcrypt
Blowfish crypt	Solar Designer	www.openwall.com
Blowfish cipher	Simon Tatham	PuTTY
Rijndael cipher	Brian Gladman	OpenBSD sys/crypto
MD5 hash and SHA1	WIDE Project	KAME kame/sys/crypto
SHA256/384/512	Aaron D. Gifford	OpenBSD sys/crypto
BIGNUM math	Michael J. Fromberger	dartmouth.edu/~sting/sw/imath

F.26. pg_freespacemap

The `pg_freespacemap` module provides a means for examining the free space map (FSM). It provides a function called `pg_freespace`, or two overloaded functions, to be precise. The functions show the value recorded in the free space map for a given page, or for all pages in the relation.

By default public access is revoked from the functions, just in case there are security issues lurking.

F.26.1. Functions

`pg_freespace(rel regclass IN, blkno bigint IN) returns int2`

Returns the amount of free space on the page of the relation, specified by `blkno`, according to the FSM.

`pg_freespace(rel regclass IN, blkno OUT bigint, avail OUT int2)`

Displays the amount of free space on each page of the relation, according to the FSM. A set of `(blkno bigint, avail int2)` tuples is returned, one tuple for each page in the relation.

The values stored in the free space map are not exact. They're rounded to precision of 1/256th of `BLCKSZ` (32 bytes with default `BLCKSZ`), and they're not kept fully up-to-date as tuples are inserted and updated.

For indexes, what is tracked is entirely-unused pages, rather than free space within pages. Therefore, the values are not meaningful, just whether a page is full or empty.

> **Note:** The interface was changed in version 8.4, to reflect the new FSM implementation introduced in the same version.

F.26.2. Sample Output

```
postgres=# SELECT * FROM pg_freespace('foo');
 blkno | avail
-------+-------
     0 |     0
     1 |     0
     2 |     0
     3 |    32
     4 |   704
     5 |   704
     6 |   704
     7 |  1216
     8 |   704
     9 |   704
    10 |   704
    11 |   704
    12 |   704
    13 |   704
    14 |   704
    15 |   704
    16 |   704
    17 |   704
    18 |   704
    19 |  3648
(20 rows)

postgres=# SELECT * FROM pg_freespace('foo', 7);
 pg_freespace
--------------
         1216
(1 row)
```

F.26.3. Author

Original version by Mark Kirkwood <markir@paradise.net.nz>. Rewritten in version 8.4 to suit new FSM implementation by Heikki Linnakangas <heikki@enterprisedb.com>

F.27. pg_prewarm

The pg_prewarm module provides a convenient way to load relation data into either the operating system buffer cache or the PostgreSQL buffer cache.

F.27.1. Functions

```
pg_prewarm(regclass, mode text default 'buffer', fork text default 'main',
           first_block int8 default null,
           last_block int8 default null) RETURNS int8
```

The first argument is the relation to be prewarmed. The second argument is the prewarming method to be used, as further discussed below; the third is the relation fork to be prewarmed, usually main. The fourth argument is the first block number to prewarm (NULL is accepted as a synonym for zero). The fifth argument is the last block number to prewarm (NULL means prewarm through the last block in the relation). The return value is the number of blocks prewarmed.

There are three available prewarming methods. prefetch issues asynchronous prefetch requests to the operating system, if this is supported, or throws an error otherwise. read reads the requested range of blocks; unlike prefetch, this is synchronous and supported on all platforms and builds, but may be slower. buffer reads the requested range of blocks into the database buffer cache.

Note that with any of these methods, attempting to prewarm more blocks than can be cached — by the OS when using prefetch or read, or by PostgreSQL when using buffer — will likely result in lower-numbered blocks being evicted as higher numbered blocks are read in. Prewarmed data also enjoys no special protection from cache evictions, so it is possible for other system activity may evict the newly prewarmed blocks shortly after they are read; conversely, prewarming may also evict other data from cache. For these reasons, prewarming is typically most useful at startup, when caches are largely empty.

F.27.2. Author

Robert Haas <rhaas@postgresql.org>

F.28. pgrowlocks

The pgrowlocks module provides a function to show row locking information for a specified table.

F.28.1. Overview

```
pgrowlocks(text) returns setof record
```

The parameter is the name of a table. The result is a set of records, with one row for each locked row within the table. The output columns are shown in Table F-19.

Table F-19. pgrowlocks Output Columns

Name	Type	Description

Name	Type	Description
locked_row	tid	Tuple ID (TID) of locked row
locker	xid	Transaction ID of locker, or multixact ID if multitransaction
multi	boolean	True if locker is a multitransaction
xids	xid[]	Transaction IDs of lockers (more than one if multitransaction)
lock_type	text[]	Lock mode of lockers (more than one if multitransaction), an array of Key Share, Share, For No Key Update, No Key Update, For Update, Update.
pids	integer[]	Process IDs of locking backends (more than one if multitransaction)

pgrowlocks takes AccessShareLock for the target table and reads each row one by one to collect the row locking information. This is not very speedy for a large table. Note that:

1. If the table as a whole is exclusive-locked by someone else, pgrowlocks will be blocked.
2. pgrowlocks is not guaranteed to produce a self-consistent snapshot. It is possible that a new row lock is taken, or an old lock is freed, during its execution.

pgrowlocks does not show the contents of locked rows. If you want to take a look at the row contents at the same time, you could do something like this:

```
SELECT * FROM accounts AS a, pgrowlocks('accounts') AS p
  WHERE p.locked_row = a.ctid;
```

Be aware however that such a query will be very inefficient.

F.28.2. Sample Output

```
test=# SELECT * FROM pgrowlocks('t1');
 locked_row | lock_type | locker | multi |   xids    |     pids
------------+-----------+--------+-------+-----------+---------------
      (0,1) | Shared    |     19 | t     | {804,805} | {29066,29068}
      (0,2) | Shared    |     19 | t     | {804,805} | {29066,29068}
      (0,3) | Exclusive |    804 | f     | {804}     | {29066}
      (0,4) | Exclusive |    804 | f     | {804}     | {29066}
(4 rows)
```

F.28.3. Author

Tatsuo Ishii

F.29. pg_stat_statements

The pg_stat_statements module provides a means for tracking execution statistics of all SQL statements executed by a server.

The module must be loaded by adding pg_stat_statements to shared_preload_libraries in postgresql.conf, because it requires additional shared memory. This means that a server restart is needed to add or remove the module.

F.29.1. The pg_stat_statements View

The statistics gathered by the module are made available via a system view named pg_stat_statements. This view contains one row for each distinct database ID, user ID and query ID (up to the maximum number of distinct statements that the module can track). The columns of the view are shown in Table F-20.

Table F-20. pg_stat_statements Columns

Name	Type	References	Description
userid	oid	pg_authid.oid	OID of user who executed the statement
dbid	oid	pg_database.oid	OID of database in which the statement was executed
queryid	bigint		Internal hash code, computed from the statement's parse tree
query	text		Text of a representative statement
calls	bigint		Number of times executed
total_time	double precision		Total time spent in the statement, in milliseconds
rows	bigint		Total number of rows retrieved or affected by the statement
shared_blks_hit	bigint		Total number of shared block cache hits by the statement
shared_blks_read	bigint		Total number of shared blocks read by the statement
shared_blks_dirtied	bigint		Total number of shared blocks dirtied by the statement
shared_blks_written	bigint		Total number of shared blocks written by the statement

Name	Type	References	Description
local_blks_hit	bigint		Total number of local block cache hits by the statement
local_blks_read	bigint		Total number of local blocks read by the statement
local_blks_dirtied	bigint		Total number of local blocks dirtied by the statement
local_blks_written	bigint		Total number of local blocks written by the statement
temp_blks_read	bigint		Total number of temp blocks read by the statement
temp_blks_written	bigint		Total number of temp blocks written by the statement
blk_read_time	double precision		Total time the statement spent reading blocks, in milliseconds (if track_io_timing is enabled, otherwise zero)
blk_write_time	double precision		Total time the statement spent writing blocks, in milliseconds (if track_io_timing is enabled, otherwise zero)

This view, and the functions pg_stat_statements_reset and pg_stat_statements, are available only in databases they have been specifically installed into by installing the pg_stat_statements extension. However, statistics are tracked across all databases of the server whenever the pg_stat_statements module is loaded into the server, regardless of presence of the view.

For security reasons, non-superusers are not allowed to see the SQL text or queryid of queries executed by other users. They can see the statistics, however, if the view has been installed in their database.

Plannable queries (that is, SELECT, INSERT, UPDATE, and DELETE) are combined into a single pg_stat_statements entry whenever they have identical query structures according to an internal hash calculation. Typically, two queries will be considered the same for this purpose if they are semantically equivalent except for the values of literal constants appearing in the query. Utility commands (that is, all other commands) are compared strictly on the basis of their textual query strings, however.

When a constant's value has been ignored for purposes of matching the query to other queries, the constant is replaced by ? in the pg_stat_statements display. The rest of the query text is that of the first query that had the particular queryid hash value associated with the pg_stat_statements

entry.

In some cases, queries with visibly different texts might get merged into a single `pg_stat_statements` entry. Normally this will happen only for semantically equivalent queries, but there is a small chance of hash collisions causing unrelated queries to be merged into one entry. (This cannot happen for queries belonging to different users or databases, however.)

Since the `queryid` hash value is computed on the post-parse-analysis representation of the queries, the opposite is also possible: queries with identical texts might appear as separate entries, if they have different meanings as a result of factors such as different `search_path` settings.

Consumers of `pg_stat_statements` may wish to use `queryid` (perhaps in combination with `dbid` and `userid`) as a more stable and reliable identifier for each entry than its query text. However, it is important to understand that there are only limited guarantees around the stability of the `queryid` hash value. Since the identifier is derived from the post-parse-analysis tree, its value is a function of, among other things, the internal object identifiers appearing in this representation. This has some counterintuitive implications. For example, `pg_stat_statements` will consider two apparently-identical queries to be distinct, if they reference a table that was dropped and recreated between the executions of the two queries. The hashing process is also sensitive to differences in machine architecture and other facets of the platform. Furthermore, it is not safe to assume that `queryid` will be stable across major versions of PostgreSQL.

As a rule of thumb, `queryid` values can be assumed to be stable and comparable only so long as the underlying server version and catalog metadata details stay exactly the same. Two servers participating in replication based on physical WAL replay can be expected to have identical `queryid` values for the same query. However, logical replication schemes do not promise to keep replicas identical in all relevant details, so `queryid` will not be a useful identifier for accumulating costs across a set of logical replicas. If in doubt, direct testing is recommended.

F.29.2. Functions

`pg_stat_statements_reset() returns void`

`pg_stat_statements_reset` discards all statistics gathered so far by `pg_stat_statements`. By default, this function can only be executed by superusers.

`pg_stat_statements(showtext boolean) returns setof record`

The `pg_stat_statements` view is defined in terms of a function also named `pg_stat_statements`. It is possible for clients to call the `pg_stat_statements` function directly, and by specifying `showtext := false` have query text be omitted (that is, the `OUT` argument that corresponds to the view's `query` column will return nulls). This feature is intended to support external tools that might wish to avoid the overhead of repeatedly retrieving query texts of indeterminate length. Such tools can instead cache the first query text observed for each entry themselves, since that is all `pg_stat_statements` itself does, and then retrieve query texts only as needed. Since the server stores query texts in a file, this approach may reduce physical I/O for repeated examination of the `pg_stat_statements` data.

F.29.3. Configuration Parameters

`pg_stat_statements.max (integer)`

`pg_stat_statements.max` is the maximum number of statements tracked by the module (i.e.,

the maximum number of rows in the `pg_stat_statements` view). If more distinct statements than that are observed, information about the least-executed statements is discarded. The default value is 5000. This parameter can only be set at server start.

`pg_stat_statements.track` (`enum`)

`pg_stat_statements.track` controls which statements are counted by the module. Specify `top` to track top-level statements (those issued directly by clients), `all` to also track nested statements (such as statements invoked within functions), or `none` to disable statement statistics collection. The default value is `top`. Only superusers can change this setting.

`pg_stat_statements.track_utility` (`boolean`)

`pg_stat_statements.track_utility` controls whether utility commands are tracked by the module. Utility commands are all those other than `SELECT`, `INSERT`, `UPDATE` and `DELETE`. The default value is `on`. Only superusers can change this setting.

`pg_stat_statements.save` (`boolean`)

`pg_stat_statements.save` specifies whether to save statement statistics across server shutdowns. If it is `off` then statistics are not saved at shutdown nor reloaded at server start. The default value is `on`. This parameter can only be set in the `postgresql.conf` file or on the server command line.

The module requires additional shared memory proportional to `pg_stat_statements.max`. Note that this memory is consumed whenever the module is loaded, even if `pg_stat_statements.track` is set to `none`.

These parameters must be set in `postgresql.conf`. Typical usage might be:

```
# postgresql.conf
shared_preload_libraries = 'pg_stat_statements'

pg_stat_statements.max = 10000
pg_stat_statements.track = all
```

F.29.4. Sample Output

```
bench=# SELECT pg_stat_statements_reset();

$ pgbench -i bench
$ pgbench -c10 -t300 bench

bench=# \x
bench=# SELECT query, calls, total_time, rows, 100.0 * shared_blks_hit /
               nullif(shared_blks_hit + shared_blks_read, 0) AS hit_percent
          FROM pg_stat_statements ORDER BY total_time DESC LIMIT 5;
-[ RECORD 1 ]---------------------------------------------------------------
query       | UPDATE pgbench_branches SET bbalance = bbalance + ? WHERE bid = ?;
calls       | 3000
total_time  | 9609.00100000002
rows        | 2836
hit_percent | 99.9778970000200936
-[ RECORD 2 ]---------------------------------------------------------------
query       | UPDATE pgbench_tellers SET tbalance = tbalance + ? WHERE tid = ?;
calls       | 3000
```

```
total_time  | 8015.156
rows        | 2990
hit_percent | 99.9731126579631345
-[ RECORD 3 ]-------------------------------------------------------------------
query       | copy pgbench_accounts from stdin
calls       | 1
total_time  | 310.624
rows        | 100000
hit_percent | 0.30395136778115501520
-[ RECORD 4 ]-------------------------------------------------------------------
query       | UPDATE pgbench_accounts SET abalance = abalance + ? WHERE aid = ?;
calls       | 3000
total_time  | 271.741999999997
rows        | 3000
hit_percent | 93.7968855088209426
-[ RECORD 5 ]-------------------------------------------------------------------
query       | alter table pgbench_accounts add primary key (aid)
calls       | 1
total_time  | 81.42
rows        | 0
hit_percent | 34.4947735191637631
```

F.29.5. Authors

Takahiro Itagaki <itagaki.takahiro@oss.ntt.co.jp>. Query normalization added by Peter Geoghegan <peter@2ndquadrant.com>.

F.30. pgstattuple

The pgstattuple module provides various functions to obtain tuple-level statistics.

F.30.1. Functions

pgstattuple(regclass) returns record

pgstattuple returns a relation's physical length, percentage of "dead" tuples, and other info. This may help users to determine whether vacuum is necessary or not. The argument is the target relation's name (optionally schema-qualified) or OID. For example:

```
test=> SELECT * FROM pgstattuple('pg_catalog.pg_proc');
-[ RECORD 1 ]------+-------
table_len          | 458752
tuple_count        | 1470
tuple_len          | 438896
tuple_percent      | 95.67
dead_tuple_count   | 11
dead_tuple_len     | 3157
dead_tuple_percent | 0.69
free_space         | 8932
free_percent       | 1.95
```

The output columns are described in Table F-21.

Table F-21. `pgstattuple` Output Columns

Column	Type	Description
`table_len`	`bigint`	Physical relation length in bytes
`tuple_count`	`bigint`	Number of live tuples
`tuple_len`	`bigint`	Total length of live tuples in bytes
`tuple_percent`	`float8`	Percentage of live tuples
`dead_tuple_count`	`bigint`	Number of dead tuples
`dead_tuple_len`	`bigint`	Total length of dead tuples in bytes
`dead_tuple_percent`	`float8`	Percentage of dead tuples
`free_space`	`bigint`	Total free space in bytes
`free_percent`	`float8`	Percentage of free space

`pgstattuple` acquires only a read lock on the relation. So the results do not reflect an instantaneous snapshot; concurrent updates will affect them.

`pgstattuple` judges a tuple is "dead" if `HeapTupleSatisfiesDirty` returns false.

`pgstattuple(text) returns record`

This is the same as `pgstattuple(regclass)`, except that the target relation is specified by TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in the future release.

`pgstatindex(regclass) returns record`

`pgstatindex` returns a record showing information about a B-tree index. For example:

```
test=> SELECT * FROM pgstatindex('pg_cast_oid_index');
-[ RECORD 1 ]------+------
version            | 2
tree_level         | 0
index_size         | 8192
root_block_no      | 1
internal_pages     | 0
leaf_pages         | 1
empty_pages        | 0
deleted_pages      | 0
avg_leaf_density   | 50.27
leaf_fragmentation | 0
```

The output columns are:

Column	Type	Description
`version`	`integer`	B-tree version number
`tree_level`	`integer`	Tree level of the root page
`index_size`	`bigint`	Total number of pages in index
`root_block_no`	`bigint`	Location of root block
`internal_pages`	`bigint`	Number of "internal" (upper-level) pages

Column	Type	Description
leaf_pages	bigint	Number of leaf pages
empty_pages	bigint	Number of empty pages
deleted_pages	bigint	Number of deleted pages
avg_leaf_density	float8	Average density of leaf pages
leaf_fragmentation	float8	Leaf page fragmentation

As with pgstattuple, the results are accumulated page-by-page, and should not be expected to represent an instantaneous snapshot of the whole index.

pgstatindex(text) returns record

This is the same as pgstatindex(regclass), except that the target index is specified by TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in the future release.

pgstatginindex(regclass) returns record

pgstatginindex returns a record showing information about a GIN index. For example:

```
test=> SELECT * FROM pgstatginindex('test_gin_index');
-[ RECORD 1 ]--+--
version        | 1
pending_pages  | 0
pending_tuples | 0
```

The output columns are:

Column	Type	Description
version	integer	GIN version number
pending_pages	integer	Number of pages in the pending list
pending_tuples	bigint	Number of tuples in the pending list

pg_relpages(regclass) returns bigint

pg_relpages returns the number of pages in the relation.

pg_relpages(text) returns bigint

This is the same as pg_relpages(regclass), except that the target relation is specified by TEXT. This function is kept because of backward-compatibility so far, and will be deprecated in the future release.

F.30.2. Authors

Tatsuo Ishii and Satoshi Nagayasu

F.31. pg_trgm

The pg_trgm module provides functions and operators for determining the similarity of alphanumeric text based on trigram matching, as well as index operator classes that support fast searching for similar strings.

F.31.1. Trigram (or Trigraph) Concepts

A trigram is a group of three consecutive characters taken from a string. We can measure the similarity of two strings by counting the number of trigrams they share. This simple idea turns out to be very effective for measuring the similarity of words in many natural languages.

> **Note:** pg_trgm ignores non-word characters (non-alphanumerics) when extracting trigrams from a string. Each word is considered to have two spaces prefixed and one space suffixed when determining the set of trigrams contained in the string. For example, the set of trigrams in the string "cat" is " c", " ca", "cat", and "at ". The set of trigrams in the string "foo|bar" is " f", " fo", "foo", "oo ", " b", " ba", "bar", and "ar ".

F.31.2. Functions and Operators

The functions provided by the pg_trgm module are shown in Table F-22, the operators in Table F-23.

Table F-22. pg_trgm Functions

Function	Returns	Description
similarity(text, text)	real	Returns a number that indicates how similar the two arguments are. The range of the result is zero (indicating that the two strings are completely dissimilar) to one (indicating that the two strings are identical).
show_trgm(text)	text[]	Returns an array of all the trigrams in the given string. (In practice this is seldom useful except for debugging.)
show_limit()	real	Returns the current similarity threshold used by the % operator. This sets the minimum similarity between two words for them to be considered similar enough to be misspellings of each other, for example.

Function	Returns	Description
set_limit(real)	real	Sets the current similarity threshold that is used by the % operator. The threshold must be between 0 and 1 (default is 0.3). Returns the same value passed in.

Table F-23. pg_trgm Operators

Operator	Returns	Description
text % text	boolean	Returns true if its arguments have a similarity that is greater than the current similarity threshold set by set_limit.
text <-> text	real	Returns the "distance" between the arguments, that is one minus the similarity() value.

F.31.3. Index Support

The pg_trgm module provides GiST and GIN index operator classes that allow you to create an index over a text column for the purpose of very fast similarity searches. These index types support the above-described similarity operators, and additionally support trigram-based index searches for LIKE, ILIKE, ~ and ~* queries. (These indexes do not support equality nor simple comparison operators, so you may need a regular B-tree index too.)

Example:

```
CREATE TABLE test_trgm (t text);
CREATE INDEX trgm_idx ON test_trgm USING gist (t gist_trgm_ops);
```

or

```
CREATE INDEX trgm_idx ON test_trgm USING gin (t gin_trgm_ops);
```

At this point, you will have an index on the t column that you can use for similarity searching. A typical query is

```
SELECT t, similarity(t, 'word') AS sml
  FROM test_trgm
  WHERE t % 'word'
  ORDER BY sml DESC, t;
```

This will return all values in the text column that are sufficiently similar to *word*, sorted from best match to worst. The index will be used to make this a fast operation even over very large data sets.

A variant of the above query is

```
SELECT t, t <-> 'word' AS dist
  FROM test_trgm
```

```
  ORDER BY dist LIMIT 10;
```

This can be implemented quite efficiently by GiST indexes, but not by GIN indexes. It will usually beat the first formulation when only a small number of the closest matches is wanted.

Beginning in PostgreSQL 9.1, these index types also support index searches for `LIKE` and `ILIKE`, for example

```
SELECT * FROM test_trgm WHERE t LIKE '%foo%bar';
```

The index search works by extracting trigrams from the search string and then looking these up in the index. The more trigrams in the search string, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

Beginning in PostgreSQL 9.3, these index types also support index searches for regular-expression matches (`~` and `~*` operators), for example

```
SELECT * FROM test_trgm WHERE t ~ '(foo|bar)';
```

The index search works by extracting trigrams from the regular expression and then looking these up in the index. The more trigrams that can be extracted from the regular expression, the more effective the index search is. Unlike B-tree based searches, the search string need not be left-anchored.

For both `LIKE` and regular-expression searches, keep in mind that a pattern with no extractable trigrams will degenerate to a full-index scan.

The choice between GiST and GIN indexing depends on the relative performance characteristics of GiST and GIN, which are discussed elsewhere. As a rule of thumb, a GIN index is faster to search than a GiST index, but slower to build or update; so GIN is better suited for static data and GiST for often-updated data.

F.31.4. Text Search Integration

Trigram matching is a very useful tool when used in conjunction with a full text index. In particular it can help to recognize misspelled input words that will not be matched directly by the full text search mechanism.

The first step is to generate an auxiliary table containing all the unique words in the documents:

```
CREATE TABLE words AS SELECT word FROM
        ts_stat('SELECT to_tsvector("simple", bodytext) FROM documents');
```

where `documents` is a table that has a text field `bodytext` that we wish to search. The reason for using the `simple` configuration with the `to_tsvector` function, instead of using a language-specific configuration, is that we want a list of the original (unstemmed) words.

Next, create a trigram index on the word column:

```
CREATE INDEX words_idx ON words USING gin(word gin_trgm_ops);
```

Now, a `SELECT` query similar to the previous example can be used to suggest spellings for misspelled words in user search terms. A useful extra test is to require that the selected words are also of similar length to the misspelled word.

> **Note:** Since the `words` table has been generated as a separate, static table, it will need to be periodically regenerated so that it remains reasonably up-to-date with the document collection. Keeping it exactly current is usually unnecessary.

F.31.5. References

GiST Development Site http://www.sai.msu.su/~megera/postgres/gist/

Tsearch2 Development Site http://www.sai.msu.su/~megera/postgres/gist/tsearch/V2/

F.31.6. Authors

Oleg Bartunov <oleg@sai.msu.su>, Moscow, Moscow University, Russia

Teodor Sigaev <teodor@sigaev.ru>, Moscow, Delta-Soft Ltd.,Russia

Documentation: Christopher Kings-Lynne

This module is sponsored by Delta-Soft Ltd., Moscow, Russia.

F.32. postgres_fdw

The postgres_fdw module provides the foreign-data wrapper postgres_fdw, which can be used to access data stored in external PostgreSQL servers.

The functionality provided by this module overlaps substantially with the functionality of the older dblink module. But postgres_fdw provides more transparent and standards-compliant syntax for accessing remote tables, and can give better performance in many cases.

To prepare for remote access using postgres_fdw:

1. Install the postgres_fdw extension using CREATE EXTENSION.
2. Create a foreign server object, using CREATE SERVER, to represent each remote database you want to connect to. Specify connection information, except user and password, as options of the server object.
3. Create a user mapping, using CREATE USER MAPPING, for each database user you want to allow to access each foreign server. Specify the remote user name and password to use as user and password options of the user mapping.
4. Create a foreign table, using CREATE FOREIGN TABLE, for each remote table you want to access. The columns of the foreign table must match the referenced remote table. You can, however, use table and/or column names different from the remote table's, if you specify the correct remote names as options of the foreign table object.

Now you need only SELECT from a foreign table to access the data stored in its underlying remote table. You can also modify the remote table using INSERT, UPDATE, or DELETE. (Of course, the remote user you have specified in your user mapping must have privileges to do these things.)

It is generally recommended that the columns of a foreign table be declared with exactly the same data types, and collations if applicable, as the referenced columns of the remote table. Although postgres_fdw is currently rather forgiving about performing data type conversions at need, surprising semantic anomalies may arise when types or collations do not match, due to the remote server interpreting WHERE clauses slightly differently from the local server.

Note that a foreign table can be declared with fewer columns, or with a different column order, than its underlying remote table has. Matching of columns to the remote table is by name, not position.

F.32.1. FDW Options of postgres_fdw

F.32.1.1. Connection Options

A foreign server using the `postgres_fdw` foreign data wrapper can have the same options that libpq accepts in connection strings, as described in Section 31.1.2, except that these options are not allowed:

- `user` and `password` (specify these for a user mapping, instead)
- `client_encoding` (this is automatically set from the local server encoding)
- `fallback_application_name` (always set to `postgres_fdw`)

Only superusers may connect to foreign servers without password authentication, so always specify the `password` option for user mappings belonging to non-superusers.

F.32.1.2. Object Name Options

These options can be used to control the names used in SQL statements sent to the remote PostgreSQL server. These options are needed when a foreign table is created with names different from the underlying remote table's names.

`schema_name`

This option, which can be specified for a foreign table, gives the schema name to use for the foreign table on the remote server. If this option is omitted, the name of the foreign table's schema is used.

`table_name`

This option, which can be specified for a foreign table, gives the table name to use for the foreign table on the remote server. If this option is omitted, the foreign table's name is used.

`column_name`

This option, which can be specified for a column of a foreign table, gives the column name to use for the column on the remote server. If this option is omitted, the column's name is used.

F.32.1.3. Cost Estimation Options

`postgres_fdw` retrieves remote data by executing queries against remote servers, so ideally the estimated cost of scanning a foreign table should be whatever it costs to be done on the remote server, plus some overhead for communication. The most reliable way to get such an estimate is to ask the remote server and then add something for overhead — but for simple queries, it may not be worth the cost of an additional remote query to get a cost estimate. So `postgres_fdw` provides the following options to control how cost estimation is done:

`use_remote_estimate`

This option, which can be specified for a foreign table or a foreign server, controls whether `postgres_fdw` issues remote `EXPLAIN` commands to obtain cost estimates. A setting for a foreign table overrides any setting for its server, but only for that table. The default is `false`.

`fdw_startup_cost`

This option, which can be specified for a foreign server, is a numeric value that is added to the estimated startup cost of any foreign-table scan on that server. This represents the additional overhead of establishing a connection, parsing and planning the query on the remote side, etc. The default value is `100`.

`fdw_tuple_cost`

This option, which can be specified for a foreign server, is a numeric value that is used as extra cost per-tuple for foreign-table scans on that server. This represents the additional overhead of data transfer between servers. You might increase or decrease this number to reflect higher or lower network delay to the remote server. The default value is `0.01`.

When `use_remote_estimate` is true, `postgres_fdw` obtains row count and cost estimates from the remote server and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. When `use_remote_estimate` is false, `postgres_fdw` performs local row count and cost estimation and then adds `fdw_startup_cost` and `fdw_tuple_cost` to the cost estimates. This local estimation is unlikely to be very accurate unless local copies of the remote table's statistics are available. Running ANALYZE on the foreign table is the way to update the local statistics; this will perform a scan of the remote table and then calculate and store statistics just as though the table were local. Keeping local statistics can be a useful way to reduce per-query planning overhead for a remote table — but if the remote table is frequently updated, the local statistics will soon be obsolete.

F.32.1.4. Updatability Options

By default all foreign tables using `postgres_fdw` are assumed to be updatable. This may be overridden using the following option:

`updatable`

This option controls whether `postgres_fdw` allows foreign tables to be modified using `INSERT`, `UPDATE` and `DELETE` commands. It can be specified for a foreign table or a foreign server. A table-level option overrides a server-level option. The default is `true`.

Of course, if the remote table is not in fact updatable, an error would occur anyway. Use of this option primarily allows the error to be thrown locally without querying the remote server. Note however that the `information_schema` views will report a `postgres_fdw` foreign table to be updatable (or not) according to the setting of this option, without any check of the remote server.

F.32.2. Connection Management

`postgres_fdw` establishes a connection to a foreign server during the first query that uses a foreign table associated with the foreign server. This connection is kept and re-used for subsequent queries in the same session. However, if multiple user identities (user mappings) are used to access the foreign server, a connection is established for each user mapping.

F.32.3. Transaction Management

During a query that references any remote tables on a foreign server, postgres_fdw opens a transaction on the remote server if one is not already open corresponding to the current local transaction. The remote transaction is committed or aborted when the local transaction commits or aborts. Savepoints are similarly managed by creating corresponding remote savepoints.

The remote transaction uses SERIALIZABLE isolation level when the local transaction has SERIALIZABLE isolation level; otherwise it uses REPEATABLE READ isolation level. This choice ensures that if a query performs multiple table scans on the remote server, it will get snapshot-consistent results for all the scans. A consequence is that successive queries within a single transaction will see the same data from the remote server, even if concurrent updates are occurring on the remote server due to other activities. That behavior would be expected anyway if the local transaction uses SERIALIZABLE or REPEATABLE READ isolation level, but it might be surprising for a READ COMMITTED local transaction. A future PostgreSQL release might modify these rules.

F.32.4. Remote Query Optimization

postgres_fdw attempts to optimize remote queries to reduce the amount of data transferred from foreign servers. This is done by sending query WHERE clauses to the remote server for execution, and by not retrieving table columns that are not needed for the current query. To reduce the risk of misexecution of queries, WHERE clauses are not sent to the remote server unless they use only built-in data types, operators, and functions. Operators and functions in the clauses must be IMMUTABLE as well.

The query that is actually sent to the remote server for execution can be examined using EXPLAIN VERBOSE.

F.32.5. Cross-Version Compatibility

postgres_fdw can be used with remote servers dating back to PostgreSQL 8.3. Read-only capability is available back to 8.1. A limitation however is that postgres_fdw generally assumes that immutable built-in functions and operators are safe to send to the remote server for execution, if they appear in a WHERE clause for a foreign table. Thus, a built-in function that was added since the remote server's release might be sent to it for execution, resulting in "function does not exist" or a similar error. This type of failure can be worked around by rewriting the query, for example by embedding the foreign table reference in a sub-SELECT with OFFSET 0 as an optimization fence, and placing the problematic function or operator outside the sub-SELECT.

F.32.6. Examples

Here is an example of creating a foreign table with postgres_fdw. First install the extension:

```
CREATE EXTENSION postgres_fdw;
```

Then create a foreign server using CREATE SERVER. In this example we wish to connect to a PostgreSQL server on host 192.83.123.89 listening on port 5432. The database to which the connection is made is named foreign_db on the remote server:

```
CREATE SERVER foreign_server
        FOREIGN DATA WRAPPER postgres_fdw
```

```
        OPTIONS (host '192.83.123.89', port '5432', dbname 'foreign_db');
```

A user mapping, defined with CREATE USER MAPPING, is needed as well to identify the role that will be used on the remote server:

```
CREATE USER MAPPING FOR local_user
        SERVER foreign_server
        OPTIONS (user 'foreign_user', password 'password');
```

Now it is possible to create a foreign table with CREATE FOREIGN TABLE. In this example we wish to access the table named `some_schema.some_table` on the remote server. The local name for it will be `foreign_table`:

```
CREATE FOREIGN TABLE foreign_table (
        id serial NOT NULL,
        data text
)
        SERVER foreign_server
        OPTIONS (schema_name 'some_schema', table_name 'some_table');
```

It's essential that the data types and other properties of the columns declared in `CREATE FOREIGN TABLE` match the actual remote table. Column names must match as well, unless you attach `column_name` options to the individual columns to show how they are named in the remote table.

F.32.7. Author

Shigeru Hanada <`shigeru.hanada@gmail.com`>

F.33. seg

This module implements a data type `seg` for representing line segments, or floating point intervals. `seg` can represent uncertainty in the interval endpoints, making it especially useful for representing laboratory measurements.

F.33.1. Rationale

The geometry of measurements is usually more complex than that of a point in a numeric continuum. A measurement is usually a segment of that continuum with somewhat fuzzy limits. The measurements come out as intervals because of uncertainty and randomness, as well as because the value being measured may naturally be an interval indicating some condition, such as the temperature range of stability of a protein.

Using just common sense, it appears more convenient to store such data as intervals, rather than pairs of numbers. In practice, it even turns out more efficient in most applications.

Further along the line of common sense, the fuzziness of the limits suggests that the use of traditional numeric data types leads to a certain loss of information. Consider this: your instrument reads 6.50, and you input this reading into the database. What do you get when you fetch it? Watch:

```
test=> select 6.50 :: float8 as "pH";
 pH
---
6.5
(1 row)
```

In the world of measurements, 6.50 is not the same as 6.5. It may sometimes be critically different. The experimenters usually write down (and publish) the digits they trust. 6.50 is actually a fuzzy interval contained within a bigger and even fuzzier interval, 6.5, with their center points being (probably) the only common feature they share. We definitely do not want such different data items to appear the same.

Conclusion? It is nice to have a special data type that can record the limits of an interval with arbitrarily variable precision. Variable in the sense that each data element records its own precision.

Check this out:

```
test=> select '6.25 .. 6.50'::seg as "pH";
          pH
------------
6.25 .. 6.50
(1 row)
```

F.33.2. Syntax

The external representation of an interval is formed using one or two floating-point numbers joined by the range operator (`..` or `...`). Alternatively, it can be specified as a center point plus or minus a deviation. Optional certainty indicators (<, > or ~) can be stored as well. (Certainty indicators are ignored by all the built-in operators, however.) Table F-24 gives an overview of allowed representations; Table F-25 shows some examples.

In Table F-24, *x*, *y*, and *delta* denote floating-point numbers. *x* and *y*, but not *delta*, can be preceded by a certainty indicator.

Table F-24. `seg` External Representations

x	Single value (zero-length interval)
x `..` *y*	Interval from *x* to *y*
x `(+-)` *delta*	Interval from *x* - *delta* to *x* + *delta*
x `..`	Open interval with lower bound *x*
`..` *x*	Open interval with upper bound *x*

Table F-25. Examples of Valid `seg` Input

`5.0`	Creates a zero-length segment (a point, if you will)
`~5.0`	Creates a zero-length segment and records ~ in the data. ~ is ignored by `seg` operations, but is preserved as a comment.

`<5.0`	Creates a point at 5.0. < is ignored but is preserved as a comment.
`>5.0`	Creates a point at 5.0. > is ignored but is preserved as a comment.
`5(+-)0.3`	Creates an interval `4.7 .. 5.3`. Note that the `(+-)` notation isn't preserved.
`50 ..`	Everything that is greater than or equal to 50
`.. 0`	Everything that is less than or equal to 0
`1.5e-2 .. 2E-2`	Creates an interval `0.015 .. 0.02`
`1 ... 2`	The same as `1...2`, or `1 .. 2`, or `1..2` (spaces around the range operator are ignored)

Because `...` is widely used in data sources, it is allowed as an alternative spelling of `..`. Unfortunately, this creates a parsing ambiguity: it is not clear whether the upper bound in `0...23` is meant to be `23` or `0.23`. This is resolved by requiring at least one digit before the decimal point in all numbers in `seg` input.

As a sanity check, `seg` rejects intervals with the lower bound greater than the upper, for example `5 .. 2`.

F.33.3. Precision

`seg` values are stored internally as pairs of 32-bit floating point numbers. This means that numbers with more than 7 significant digits will be truncated.

Numbers with 7 or fewer significant digits retain their original precision. That is, if your query returns 0.00, you will be sure that the trailing zeroes are not the artifacts of formatting: they reflect the precision of the original data. The number of leading zeroes does not affect precision: the value 0.0067 is considered to have just 2 significant digits.

F.33.4. Usage

The `seg` module includes a GiST index operator class for `seg` values. The operators supported by the GiST operator class are shown in Table F-26.

Table F-26. Seg GiST Operators

Operator	Description
`[a, b] << [c, d]`	[a, b] is entirely to the left of [c, d]. That is, [a, b] << [c, d] is true if b < c and false otherwise.
`[a, b] >> [c, d]`	[a, b] is entirely to the right of [c, d]. That is, [a, b] >> [c, d] is true if a > d and false otherwise.
`[a, b] &< [c, d]`	Overlaps or is left of — This might be better read as "does not extend to right of". It is true when b <= d.
`[a, b] &> [c, d]`	Overlaps or is right of — This might be better read as "does not extend to left of". It is true when a >= c.

Operator	Description
`[a, b] = [c, d]`	Same as — The segments [a, b] and [c, d] are identical, that is, a = c and b = d.
`[a, b] && [c, d]`	The segments [a, b] and [c, d] overlap.
`[a, b] @> [c, d]`	The segment [a, b] contains the segment [c, d], that is, a <= c and b >= d.
`[a, b] <@ [c, d]`	The segment [a, b] is contained in [c, d], that is, a >= c and b <= d.

(Before PostgreSQL 8.2, the containment operators `@>` and `<@` were respectively called `@` and `~`. These names are still available, but are deprecated and will eventually be retired. Notice that the old names are reversed from the convention formerly followed by the core geometric data types!)

The standard B-tree operators are also provided, for example

Operator	Description
`[a, b] < [c, d]`	Less than
`[a, b] > [c, d]`	Greater than

These operators do not make a lot of sense for any practical purpose but sorting. These operators first compare (a) to (c), and if these are equal, compare (b) to (d). That results in reasonably good sorting in most cases, which is useful if you want to use ORDER BY with this type.

F.33.5. Notes

For examples of usage, see the regression test `sql/seg.sql`.

The mechanism that converts `(+-)` to regular ranges isn't completely accurate in determining the number of significant digits for the boundaries. For example, it adds an extra digit to the lower boundary if the resulting interval includes a power of ten:

```
postgres=> select '10(+-)1'::seg as seg;
      seg
---------
9.0 .. 11             -- should be: 9 .. 11
```

The performance of an R-tree index can largely depend on the initial order of input values. It may be very helpful to sort the input table on the `seg` column; see the script `sort-segments.pl` for an example.

F.33.6. Credits

Original author: Gene Selkov, Jr. <`selkovjr@mcs.anl.gov`>, Mathematics and Computer Science Division, Argonne National Laboratory.

My thanks are primarily to Prof. Joe Hellerstein (http://db.cs.berkeley.edu/jmh/) for elucidating the gist of the GiST (http://gist.cs.berkeley.edu/). I am also grateful to all Postgres developers, present and past, for enabling myself to create my own world and live undisturbed in it. And I would like to acknowledge my gratitude to Argonne Lab and to the U.S. Department of Energy for the years of faithful support of my database research.

F.34. sepgsql

sepgsql is a loadable module that supports label-based mandatory access control (MAC) based on SELinux security policy.

> **Warning**
>
> The current implementation has significant limitations, and does not enforce mandatory access control for all actions. See Section F.34.7.

F.34.1. Overview

This module integrates with SELinux to provide an additional layer of security checking above and beyond what is normally provided by PostgreSQL. From the perspective of SELinux, this module allows PostgreSQL to function as a user-space object manager. Each table or function access initiated by a DML query will be checked against the system security policy. This check is in addition to the usual SQL permissions checking performed by PostgreSQL.

SELinux access control decisions are made using security labels, which are represented by strings such as system_u:object_r:sepgsql_table_t:s0. Each access control decision involves two labels: the label of the subject attempting to perform the action, and the label of the object on which the operation is to be performed. Since these labels can be applied to any sort of object, access control decisions for objects stored within the database can be (and, with this module, are) subjected to the same general criteria used for objects of any other type, such as files. This design is intended to allow a centralized security policy to protect information assets independent of the particulars of how those assets are stored.

The SECURITY LABEL statement allows assignment of a security label to a database object.

F.34.2. Installation

sepgsql can only be used on Linux 2.6.28 or higher with SELinux enabled. It is not available on any other platform. You will also need libselinux 2.1.10 or higher and selinux-policy 3.9.13 or higher (although some distributions may backport the necessary rules into older policy versions).

The sestatus command allows you to check the status of SELinux. A typical display is:

```
$ sestatus
SELinux status:                 enabled
SELinuxfs mount:                /selinux
Current mode:                   enforcing
Mode from config file:          enforcing
Policy version:                 24
Policy from config file:        targeted
```

If SELinux is disabled or not installed, you must set that product up first before installing this module.

To build this module, include the option --with-selinux in your PostgreSQL configure command. Be sure that the libselinux-devel RPM is installed at build time.

To use this module, you must include sepgsql in the shared_preload_libraries parameter in postgresql.conf. The module will not function correctly if loaded in any other manner. Once the module is loaded, you should execute sepgsql.sql in each database. This will install functions needed for security label management, and assign initial security labels.

Here is an example showing how to initialize a fresh database cluster with `sepgsql` functions and security labels installed. Adjust the paths shown as appropriate for your installation:

```
$ export PGDATA=/path/to/data/directory
$ initdb
$ vi $PGDATA/postgresql.conf
  change
    #shared_preload_libraries = ''                # (change requires restart)
  to
    shared_preload_libraries = 'sepgsql'          # (change requires restart)
$ for DBNAME in template0 template1 postgres; do
    postgres --single -F -c exit_on_error=true $DBNAME \
      </usr/local/pgsql/share/contrib/sepgsql.sql >/dev/null
  done
```

Please note that you may see some or all of the following notifications depending on the particular versions you have of libselinux and selinux-policy:

```
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 33 has invalid object type db_blo
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 36 has invalid object type db_lan
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 37 has invalid object type db_lan
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 38 has invalid object type db_lan
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 39 has invalid object type db_lan
/etc/selinux/targeted/contexts/sepgsql_contexts:  line 40 has invalid object type db_lan
```

These messages are harmless and should be ignored.

If the installation process completes without error, you can now start the server normally.

F.34.3. Regression Tests

Due to the nature of SELinux, running the regression tests for `sepgsql` requires several extra configuration steps, some of which must be done as root. The regression tests will not be run by an ordinary `make check` or `make installcheck` command; you must set up the configuration and then invoke the test script manually. The tests must be run in the `contrib/sepgsql` directory of a configured PostgreSQL build tree. Although they require a build tree, the tests are designed to be executed against an installed server, that is they are comparable to `make installcheck` not `make check`.

First, set up `sepgsql` in a working database according to the instructions in Section F.34.2. Note that the current operating system user must be able to connect to the database as superuser without password authentication.

Second, build and install the policy package for the regression test. The `sepgsql-regtest` policy is a special purpose policy package which provides a set of rules to be allowed during the regression tests. It should be built from the policy source file `sepgsql-regtest.te`, which is done using `make` with a Makefile supplied by SELinux. You will need to locate the appropriate Makefile on your system; the path shown below is only an example. Once built, install this policy package using the `semodule` command, which loads supplied policy packages into the kernel. If the package is correctly installed, `semodule -l` should list `sepgsql-regtest` as an available policy package:

```
$ cd .../contrib/sepgsql
$ make -f /usr/share/selinux/devel/Makefile
$ sudo semodule -u sepgsql-regtest.pp
$ sudo semodule -l | grep sepgsql
sepgsql-regtest 1.07
```

Third, turn on `sepgsql_regression_test_mode`. For security reasons, the rules in `sepgsql-regtest` are not enabled by default; the `sepgsql_regression_test_mode` parameter enables the rules needed to launch the regression tests. It can be turned on using the `setsebool` command:

```
$ sudo setsebool sepgsql_regression_test_mode on
$ getsebool sepgsql_regression_test_mode
sepgsql_regression_test_mode --> on
```

Fourth, verify your shell is operating in the `unconfined_t` domain:

```
$ id -Z
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
```

See Section F.34.8 for details on adjusting your working domain, if necessary.

Finally, run the regression test script:

```
$ ./test_sepgsql
```

This script will attempt to verify that you have done all the configuration steps correctly, and then it will run the regression tests for the `sepgsql` module.

After completing the tests, it's recommended you disable the `sepgsql_regression_test_mode` parameter:

```
$ sudo setsebool sepgsql_regression_test_mode off
```

You might prefer to remove the `sepgsql-regtest` policy entirely:

```
$ sudo semodule -r sepgsql-regtest
```

F.34.4. GUC Parameters

`sepgsql.permissive` (`boolean`)

This parameter enables `sepgsql` to function in permissive mode, regardless of the system setting. The default is off. This parameter can only be set in the `postgresql.conf` file or on the server command line.

When this parameter is on, `sepgsql` functions in permissive mode, even if SELinux in general is working in enforcing mode. This parameter is primarily useful for testing purposes.

`sepgsql.debug_audit` (`boolean`)

This parameter enables the printing of audit messages regardless of the system policy settings. The default is off, which means that messages will be printed according to the system settings.

The security policy of SELinux also has rules to control whether or not particular accesses are logged. By default, access violations are logged, but allowed accesses are not.

This parameter forces all possible logging to be turned on, regardless of the system policy.

F.34.5. Features

F.34.5.1. Controlled Object Classes

The security model of SELinux describes all the access control rules as relationships between a subject entity (typically, a client of the database) and an object entity (such as a database object), each of which is identified by a security label. If access to an unlabeled object is attempted, the object is treated as if it were assigned the label `unlabeled_t`.

Currently, `sepgsql` allows security labels to be assigned to schemas, tables, columns, sequences, views, and functions. When `sepgsql` is in use, security labels are automatically assigned to supported database objects at creation time. This label is called a default security label, and is decided according to the system security policy, which takes as input the creator's label, the label assigned to the new object's parent object and optionally name of the constructed object.

A new database object basically inherits the security label of the parent object, except when the security policy has special rules known as type-transition rules, in which case a different label may be applied. For schemas, the parent object is the current database; for tables, sequences, views, and functions, it is the containing schema; for columns, it is the containing table.

F.34.5.2. DML Permissions

For tables, `db_table:select`, `db_table:insert`, `db_table:update` or `db_table:delete` are checked for all the referenced target tables depending on the kind of statement; in addition, `db_table:select` is also checked for all the tables that contain columns referenced in the `WHERE` or `RETURNING` clause, as a data source for `UPDATE`, and so on.

Column-level permissions will also be checked for each referenced column. `db_column:select` is checked on not only the columns being read using `SELECT`, but those being referenced in other DML statements; `db_column:update` or `db_column:insert` will also be checked for columns being modified by `UPDATE` or `INSERT`.

For example, consider:

```
UPDATE t1 SET x = 2, y = md5sum(y) WHERE z = 100;
```

Here, `db_column:update` will be checked for `t1.x`, since it is being updated, `db_column:{select update}` will be checked for `t1.y`, since it is both updated and referenced, and `db_column:select` will be checked for `t1.z`, since it is only referenced. `db_table:{select update}` will also be checked at the table level.

For sequences, `db_sequence:get_value` is checked when we reference a sequence object using `SELECT`; however, note that we do not currently check permissions on execution of corresponding functions such as `lastval()`.

For views, `db_view:expand` will be checked, then any other required permissions will be checked on the objects being expanded from the view, individually.

For functions, `db_procedure:{execute}` will be checked when user tries to execute a function as a part of query, or using fast-path invocation. If this function is a trusted procedure, it also checks `db_procedure:{entrypoint}` permission to check whether it can perform as entry point of trusted procedure.

In order to access any schema object, `db_schema:search` permission is required on the containing schema. When an object is referenced without schema qualification, schemas on which this permission is not present will not be searched (just as if the user did not have `USAGE` privilege on the schema).

If an explicit schema qualification is present, an error will occur if the user does not have the requisite permission on the named schema.

The client must be allowed to access all referenced tables and columns, even if they originated from views which were then expanded, so that we apply consistent access control rules independent of the manner in which the table contents are referenced.

The default database privilege system allows database superusers to modify system catalogs using DML commands, and reference or modify toast tables. These operations are prohibited when `sepgsql` is enabled.

F.34.5.3. DDL Permissions

SELinux defines several permissions to control common operations for each object type; such as creation, alter, drop and relabel of security label. In addition, several object types have special permissions to control their characteristic operations; such as addition or deletion of name entries within a particular schema.

Creating a new database object requires `create` permission. SELinux will grant or deny this permission based on the client's security label and the proposed security label for the new object. In some cases, additional privileges are required:

- CREATE DATABASE additionally requires `getattr` permission for the source or template database.
- Creating a schema object additionally requires `add_name` permission on the parent schema.
- Creating a table additionally requires permission to create each individual table column, just as if each table column were a separate top-level object.
- Creating a function marked as `LEAKPROOF` additionally requires `install` permission. (This permission is also checked when `LEAKPROOF` is set for an existing function.)

When `DROP` command is executed, `drop` will be checked on the object being removed. Permissions will be also checked for objects dropped indirectly via `CASCADE`. Deletion of objects contained within a particular schema (tables, views, sequences and procedures) additionally requires `remove_name` on the schema.

When `ALTER` command is executed, `setattr` will be checked on the object being modified for each object types, except for subsidiary objects such as the indexes or triggers of a table, where permissions are instead checked on the parent object. In some cases, additional permissions are required:

- Moving an object to a new schema additionally requires `remove_name` permission on the old schema and `add_name` permission on the new one.
- Setting the `LEAKPROOF` attribute on a function requires `install` permission.
- Using SECURITY LABEL on an object additionally requires `relabelfrom` permission for the object in conjunction with its old security label and `relabelto` permission for the object in conjunction with its new security label. (In cases where multiple label providers are installed and the user tries to set a security label, but it is not managed by SELinux, only `setattr` should be checked here. This is currently not done due to implementation restrictions.)

F.34.5.4. Trusted Procedures

Trusted procedures are similar to security definer functions or setuid commands. SELinux provides a feature to allow trusted code to run using a security label different from that of the client, generally for the purpose of providing highly controlled access to sensitive data (e.g. rows might be omitted, or the precision of stored values might be reduced). Whether or not a function acts as a trusted procedure is controlled by its security label and the operating system security policy. For example:

```
postgres=# CREATE TABLE customer (
               cid     int primary key,
               cname   text,
               credit  text
           );
CREATE TABLE
postgres=# SECURITY LABEL ON COLUMN customer.credit
               IS 'system_u:object_r:sepgsql_secret_table_t:s0';
SECURITY LABEL
postgres=# CREATE FUNCTION show_credit(int) RETURNS text
             AS 'SELECT regexp_replace(credit, "-[0-9]+$", "-xxxx", "g")
                         FROM customer WHERE cid = $1'
           LANGUAGE sql;
CREATE FUNCTION
postgres=# SECURITY LABEL ON FUNCTION show_credit(int)
               IS 'system_u:object_r:sepgsql_trusted_proc_exec_t:s0';
SECURITY LABEL
```

The above operations should be performed by an administrative user.

```
postgres=# SELECT * FROM customer;
ERROR:  SELinux: security policy violation
postgres=# SELECT cid, cname, show_credit(cid) FROM customer;
 cid | cname  |     show_credit
-----+--------+---------------------
   1 | taro   | 1111-2222-3333-xxxx
   2 | hanako | 5555-6666-7777-xxxx
(2 rows)
```

In this case, a regular user cannot reference `customer.credit` directly, but a trusted procedure `show_credit` allows him to print the credit card numbers of customers with some of the digits masked out.

F.34.5.5. Dynamic Domain Transitions

It is possible to use SELinux's dynamic domain transition feature to switch the security label of the client process, the client domain, to a new context, if that is allowed by the security policy. The client domain needs the `setcurrent` permission and also `dyntransition` from the old to the new domain.

Dynamic domain transitions should be considered carefully, because they allow users to switch their label, and therefore their privileges, at their option, rather than (as in the case of a trusted procedure) as mandated by the system. Thus, the `dyntransition` permission is only considered safe when used to switch to a domain with a smaller set of privileges than the original one. For example:

```
regression=# select sepgsql_getcon();
                    sepgsql_getcon
-----------------------------------------------------
```

```
 unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
(1 row)

regression=# SELECT sepgsql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-s0:c1.c4')
 sepgsql_setcon
----------------
 t
(1 row)

regression=# SELECT sepgsql_setcon('unconfined_u:unconfined_r:unconfined_t:s0-s0:c1.c102
ERROR:  SELinux: security policy violation
```

In this example above we were allowed to switch from the larger MCS range `c1.c1023` to the smaller range `c1.c4`, but switching back was denied.

A combination of dynamic domain transition and trusted procedure enables an interesting use case that fits the typical process life-cycle of connection pooling software. Even if your connection pooling software is not allowed to run most of SQL commands, you can allow it to switch the security label of the client using the `sepgsql_setcon()` function from within a trusted procedure; that should take some credential to authorize the request to switch the client label. After that, this session will have the privileges of the target user, rather than the connection pooler. The connection pooler can later revert the security label change by again using `sepgsql_setcon()` with `NULL` argument, again invoked from within a trusted procedure with appropriate permissions checks. The point here is that only the trusted procedure actually has permission to change the effective security label, and only does so when given proper credentials. Of course, for secure operation, the credential store (table, procedure definition, or whatever) must be protected from unauthorized access.

F.34.5.6. Miscellaneous

We reject the LOAD command across the board, because any module loaded could easily circumvent security policy enforcement.

F.34.6. Sepgsql Functions

Table F-27 shows the available functions.

Table F-27. Sepgsql Functions

`sepgsql_getcon() returns text`	Returns the client domain, the current security label of the client.
`sepgsql_setcon(text) returns bool`	Switches the client domain of the current session to the new domain, if allowed by the security policy. It also accepts `NULL` input as a request to transition to the client's original domain.
`sepgsql_mcstrans_in(text) returns text`	Translates the given qualifies MLS/MCS range into raw format if the mcstrans daemon is running.

`sepgsql_mcstrans_out(text) returns text`	Translates the given raw MCS/MCS range into qualified format if the mcstrans daemon is running.
`sepgsql_restorecon(text) returns bool`	Sets up initial security labels for all objects within the current database. The argument may be NULL, or the name of a specfile to be used as alternative of the system default.

F.34.7. Limitations

Data Definition Language (DDL) Permissions

Due to implementation restrictions, some DDL operations do not check permissions.

Data Control Language (DCL) Permissions

Due to implementation restrictions, DCL operations do not check permissions.

Row-level access control

PostgreSQL does not support row-level access; therefore, `sepgsql` does not support it either.

Covert channels

`sepgsql` does not try to hide the existence of a certain object, even if the user is not allowed to reference it. For example, we can infer the existence of an invisible object as a result of primary key conflicts, foreign key violations, and so on, even if we cannot obtain the contents of the object. The existence of a top secret table cannot be hidden; we only hope to conceal its contents.

F.34.8. External Resources

SE-PostgreSQL Introduction[4]

This wiki page provides a brief overview, security design, architecture, administration and upcoming features.

Fedora SELinux User Guide[5]

This document provides a wide spectrum of knowledge to administer SELinux on your systems. It focuses primarily on Fedora, but is not limited to Fedora.

Fedora SELinux FAQ[6]

This document answers frequently asked questions about SELinux. It focuses primarily on Fedora, but is not limited to Fedora.

F.34.9. Author

KaiGai Kohei <kaigai@ak.jp.nec.com>

4. http://wiki.postgresql.org/wiki/SEPostgreSQL
5. http://docs.fedoraproject.org/selinux-user-guide/
6. http://docs.fedoraproject.org/selinux-faq

F.35. spi

The spi module provides several workable examples of using SPI and triggers. While these functions are of some value in their own right, they are even more useful as examples to modify for your own purposes. The functions are general enough to be used with any table, but you have to specify table and field names (as described below) while creating a trigger.

Each of the groups of functions described below is provided as a separately-installable extension.

F.35.1. refint — Functions for Implementing Referential Integrity

`check_primary_key()` and `check_foreign_key()` are used to check foreign key constraints. (This functionality is long since superseded by the built-in foreign key mechanism, of course, but the module is still useful as an example.)

`check_primary_key()` checks the referencing table. To use, create a `BEFORE INSERT OR UPDATE` trigger using this function on a table referencing another table. Specify as the trigger arguments: the referencing table's column name(s) which form the foreign key, the referenced table name, and the column names in the referenced table which form the primary/unique key. To handle multiple foreign keys, create a trigger for each reference.

`check_foreign_key()` checks the referenced table. To use, create a `BEFORE DELETE OR UPDATE` trigger using this function on a table referenced by other table(s). Specify as the trigger arguments: the number of referencing tables for which the function has to perform checking, the action if a referencing key is found (`cascade` — to delete the referencing row, `restrict` — to abort transaction if referencing keys exist, `setnull` — to set referencing key fields to null), the triggered table's column names which form the primary/unique key, then the referencing table name and column names (repeated for as many referencing tables as were specified by first argument). Note that the primary/unique key columns should be marked NOT NULL and should have a unique index.

There are examples in `refint.example`.

F.35.2. timetravel — Functions for Implementing Time Travel

Long ago, PostgreSQL had a built-in time travel feature that kept the insert and delete times for each tuple. This can be emulated using these functions. To use these functions, you must add to a table two columns of `abstime` type to store the date when a tuple was inserted (start_date) and changed/deleted (stop_date):

```
CREATE TABLE mytab (
        ...             ...
        start_date      abstime,
        stop_date       abstime
        ...             ...
);
```

The columns can be named whatever you like, but in this discussion we'll call them start_date and stop_date.

When a new row is inserted, start_date should normally be set to current time, and stop_date to `infinity`. The trigger will automatically substitute these values if the inserted data contains nulls in

these columns. Generally, inserting explicit non-null data in these columns should only be done when re-loading dumped data.

Tuples with stop_date equal to `infinity` are "valid now", and can be modified. Tuples with a finite stop_date cannot be modified anymore — the trigger will prevent it. (If you need to do that, you can turn off time travel as shown below.)

For a modifiable row, on update only the stop_date in the tuple being updated will be changed (to current time) and a new tuple with the modified data will be inserted. Start_date in this new tuple will be set to current time and stop_date to `infinity`.

A delete does not actually remove the tuple but only sets its stop_date to current time.

To query for tuples "valid now", include `stop_date = 'infinity'` in the query's WHERE condition. (You might wish to incorporate that in a view.) Similarly, you can query for tuples valid at any past time with suitable conditions on start_date and stop_date.

`timetravel()` is the general trigger function that supports this behavior. Create a `BEFORE INSERT OR UPDATE OR DELETE` trigger using this function on each time-traveled table. Specify two trigger arguments: the actual names of the start_date and stop_date columns. Optionally, you can specify one to three more arguments, which must refer to columns of type `text`. The trigger will store the name of the current user into the first of these columns during INSERT, the second column during UPDATE, and the third during DELETE.

`set_timetravel()` allows you to turn time-travel on or off for a table. `set_timetravel('mytab', 1)` will turn TT ON for table `mytab`. `set_timetravel('mytab', 0)` will turn TT OFF for table `mytab`. In both cases the old status is reported. While TT is off, you can modify the start_date and stop_date columns freely. Note that the on/off status is local to the current database session — fresh sessions will always start out with TT ON for all tables.

`get_timetravel()` returns the TT state for a table without changing it.

There is an example in `timetravel.example`.

F.35.3. autoinc — Functions for Autoincrementing Fields

`autoinc()` is a trigger that stores the next value of a sequence into an integer field. This has some overlap with the built-in "serial column" feature, but it is not the same: `autoinc()` will override attempts to substitute a different field value during inserts, and optionally it can be used to increment the field during updates, too.

To use, create a `BEFORE INSERT` (or optionally `BEFORE INSERT OR UPDATE`) trigger using this function. Specify two trigger arguments: the name of the integer column to be modified, and the name of the sequence object that will supply values. (Actually, you can specify any number of pairs of such names, if you'd like to update more than one autoincrementing column.)

There is an example in `autoinc.example`.

F.35.4. insert_username — Functions for Tracking Who Changed a Table

`insert_username()` is a trigger that stores the current user's name into a text field. This can be useful for tracking who last modified a particular row within a table.

To use, create a `BEFORE INSERT` and/or `UPDATE` trigger using this function. Specify a single trigger argument: the name of the text column to be modified.

There is an example in `insert_username.example`.

F.35.5. moddatetime — Functions for Tracking Last Modification Time

`moddatetime()` is a trigger that stores the current time into a `timestamp` field. This can be useful for tracking the last modification time of a particular row within a table.

To use, create a `BEFORE UPDATE` trigger using this function. Specify a single trigger argument: the name of the column to be modified. The column must be of type `timestamp` or `timestamp with time zone`.

There is an example in `moddatetime.example`.

F.36. sslinfo

The `sslinfo` module provides information about the SSL certificate that the current client provided when connecting to PostgreSQL. The module is useless (most functions will return NULL) if the current connection does not use SSL.

This extension won't build at all unless the installation was configured with `--with-openssl`.

F.36.1. Functions Provided

`ssl_is_used() returns boolean`

Returns TRUE if current connection to server uses SSL, and FALSE otherwise.

`ssl_version() returns text`

Returns the name of the protocol used for the SSL connection (e.g. SSLv2, SSLv3, or TLSv1).

`ssl_cipher() returns text`

Returns the name of the cipher used for the SSL connection (e.g. DHE-RSA-AES256-SHA).

`ssl_client_cert_present() returns boolean`

Returns TRUE if current client has presented a valid SSL client certificate to the server, and FALSE otherwise. (The server might or might not be configured to require a client certificate.)

`ssl_client_serial() returns numeric`

Returns serial number of current client certificate. The combination of certificate serial number and certificate issuer is guaranteed to uniquely identify a certificate (but not its owner — the owner ought to regularly change his keys, and get new certificates from the issuer).

So, if you run your own CA and allow only certificates from this CA to be accepted by the server, the serial number is the most reliable (albeit not very mnemonic) means to identify a user.

`ssl_client_dn() returns text`

Returns the full subject of the current client certificate, converting character data into the current database encoding. It is assumed that if you use non-ASCII characters in the certificate names, your database is able to represent these characters, too. If your database uses the SQL_ASCII encoding, non-ASCII characters in the name will be represented as UTF-8 sequences.

The result looks like `/CN=Somebody /C=Some country/O=Some organization`.

`ssl_issuer_dn() returns text`

Returns the full issuer name of the current client certificate, converting character data into the current database encoding. Encoding conversions are handled the same as for `ssl_client_dn`.

The combination of the return value of this function with the certificate serial number uniquely identifies the certificate.

This function is really useful only if you have more than one trusted CA certificate in your server's `root.crt` file, or if this CA has issued some intermediate certificate authority certificates.

`ssl_client_dn_field(fieldname text) returns text`

This function returns the value of the specified field in the certificate subject, or NULL if the field is not present. Field names are string constants that are converted into ASN1 object identifiers using the OpenSSL object database. The following values are acceptable:

```
commonName (alias CN)
surname (alias SN)
name
givenName (alias GN)
countryName (alias C)
localityName (alias L)
stateOrProvinceName (alias ST)
organizationName (alias O)
organizationUnitName (alias OU)
title
description
initials
postalCode
streetAddress
generationQualifier
description
dnQualifier
x500UniqueIdentifier
pseudonym
role
emailAddress
```

All of these fields are optional, except `commonName`. It depends entirely on your CA's policy which of them would be included and which wouldn't. The meaning of these fields, however, is strictly defined by the X.500 and X.509 standards, so you cannot just assign arbitrary meaning to them.

`ssl_issuer_field(fieldname text) returns text`

Same as `ssl_client_dn_field`, but for the certificate issuer rather than the certificate subject.

F.36.2. Author

Victor Wagner <`vitus@cryptocom.ru`>, Cryptocom LTD

E-Mail of Cryptocom OpenSSL development group: <`openssl@cryptocom.ru`>

F.37. tablefunc

The `tablefunc` module includes various functions that return tables (that is, multiple rows). These functions are useful both in their own right and as examples of how to write C functions that return multiple rows.

F.37.1. Functions Provided

Table F-28 shows the functions provided by the `tablefunc` module.

Table F-28. `tablefunc` Functions

Function	Returns	Description
`normal_rand(int numvals, float8 mean, float8 stddev)`	`setof float8`	Produces a set of normally distributed random values
`crosstab(text sql)`	`setof record`	Produces a "pivot table" containing row names plus *N* value columns, where *N* is determined by the row type specified in the calling query
`crosstabN(text sql)`	`setof table_crosstab_N`	Produces a "pivot table" containing row names plus *N* value columns. `crosstab2`, `crosstab3`, and `crosstab4` are predefined, but you can create additional `crosstabN` functions as described below
`crosstab(text source_sql, text category_sql)`	`setof record`	Produces a "pivot table" with the value columns specified by a second query
`crosstab(text sql, int N)`	`setof record`	Obsolete version of `crosstab(text)`. The parameter *N* is now ignored, since the number of value columns is always determined by the calling query
`connectby(text relname, text keyid_fld, text parent_keyid_fld [, text orderby_fld ], text start_with, int max_depth [, text branch_delim ])`	`setof record`	Produces a representation of a hierarchical tree structure

F.37.1.1. `normal_rand`

```
normal_rand(int numvals, float8 mean, float8 stddev) returns setof float8
```

`normal_rand` produces a set of normally distributed random values (Gaussian distribution).

`numvals` is the number of values to be returned from the function. `mean` is the mean of the normal distribution of values and `stddev` is the standard deviation of the normal distribution of values.

For example, this call requests 1000 values with a mean of 5 and a standard deviation of 3:

```
test=# SELECT * FROM normal_rand(1000, 5, 3);
     normal_rand
----------------------
     1.56556322244898
     9.10040991424657
     5.36957140345079
   -0.369151492880995
    0.283600703686639
       .
       .
       .
     4.82992125404908
     9.71308014517282
     2.49639286969028
(1000 rows)
```

F.37.1.2. `crosstab(text)`

```
crosstab(text sql)
crosstab(text sql, int N)
```

The `crosstab` function is used to produce "pivot" displays, wherein data is listed across the page rather than down. For example, we might have data like

```
row1    val11
row1    val12
row1    val13
...
row2    val21
row2    val22
row2    val23
...
```

which we wish to display like

```
row1    val11   val12   val13   ...
row2    val21   val22   val23   ...
...
```

The `crosstab` function takes a text parameter that is a SQL query producing raw data formatted in the first way, and produces a table formatted in the second way.

The `sql` parameter is a SQL statement that produces the source set of data. This statement must return one `row_name` column, one `category` column, and one `value` column. `N` is an obsolete parameter, ignored if supplied (formerly this had to match the number of output value columns, but now that is determined by the calling query).

For example, the provided query might produce a set something like:

```
 row_name    cat    value
```

```
----------+-------+-------
  row1      cat1    val1
  row1      cat2    val2
  row1      cat3    val3
  row1      cat4    val4
  row2      cat1    val5
  row2      cat2    val6
  row2      cat3    val7
  row2      cat4    val8
```

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM crosstab('...') AS ct(row_name text, category_1 text, category_2 text);
```

This example produces a set something like:

```
           <== value  columns  ==>
 row_name   category_1   category_2
----------+------------+------------
  row1        val1         val2
  row2        val5         val6
```

The `FROM` clause must define the output as one `row_name` column (of the same data type as the first result column of the SQL query) followed by N `value` columns (all of the same data type as the third result column of the SQL query). You can set up as many output value columns as you wish. The names of the output columns are up to you.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. It fills the output `value` columns, left to right, with the `value` fields from these rows. If there are fewer rows in a group than there are output `value` columns, the extra output columns are filled with nulls; if there are more rows, the extra input rows are skipped.

In practice the SQL query should always specify `ORDER BY 1,2` to ensure that the input rows are properly ordered, that is, values with the same `row_name` are brought together and correctly ordered within the row. Notice that `crosstab` itself does not pay any attention to the second column of the query result; it's just there to be ordered by, to control the order in which the third-column values appear across the page.

Here is a complete example:

```
CREATE TABLE ct(id SERIAL, rowid TEXT, attribute TEXT, value TEXT);
INSERT INTO ct(rowid, attribute, value) VALUES('test1','att1','val1');
INSERT INTO ct(rowid, attribute, value) VALUES('test1','att2','val2');
INSERT INTO ct(rowid, attribute, value) VALUES('test1','att3','val3');
INSERT INTO ct(rowid, attribute, value) VALUES('test1','att4','val4');
INSERT INTO ct(rowid, attribute, value) VALUES('test2','att1','val5');
INSERT INTO ct(rowid, attribute, value) VALUES('test2','att2','val6');
INSERT INTO ct(rowid, attribute, value) VALUES('test2','att3','val7');
INSERT INTO ct(rowid, attribute, value) VALUES('test2','att4','val8');

SELECT *
FROM crosstab(
  'select rowid, attribute, value
   from ct
```

```
   where attribute = ”att2” or attribute = ”att3”
   order by 1,2’)
AS ct(row_name text, category_1 text, category_2 text, category_3 text);

 row_name | category_1 | category_2 | category_3
----------+------------+------------+------------
 test1    | val2       | val3       |
 test2    | val6       | val7       |
(2 rows)
```

You can avoid always having to write out a `FROM` clause to define the output columns, by setting up a custom crosstab function that has the desired output row type wired into its definition. This is described in the next section. Another possibility is to embed the required `FROM` clause in a view definition.

F.37.1.3. `crosstabN(text)`

```
crosstabN(text sql)
```

The `crosstabN` functions are examples of how to set up custom wrappers for the general `crosstab` function, so that you need not write out column names and types in the calling `SELECT` query. The `tablefunc` module includes `crosstab2`, `crosstab3`, and `crosstab4`, whose output row types are defined as

```
CREATE TYPE tablefunc_crosstab_N AS (
    row_name TEXT,
    category_1 TEXT,
    category_2 TEXT,
        .
        .
        .
    category_N TEXT
);
```

Thus, these functions can be used directly when the input query produces `row_name` and `value` columns of type `text`, and you want 2, 3, or 4 output values columns. In all other ways they behave exactly as described above for the general `crosstab` function.

For instance, the example given in the previous section would also work as

```
SELECT *
FROM crosstab3(
  ’select rowid, attribute, value
   from ct
   where attribute = ”att2” or attribute = ”att3”
   order by 1,2’);
```

These functions are provided mostly for illustration purposes. You can create your own return types and functions based on the underlying `crosstab()` function. There are two ways to do it:

- Create a composite type describing the desired output columns, similar to the examples in `contrib/tablefunc/tablefunc--1.0.sql`. Then define a unique function name accepting

one `text` parameter and returning `setof your_type_name`, but linking to the same underlying `crosstab` C function. For example, if your source data produces row names that are `text`, and values that are `float8`, and you want 5 value columns:

```
CREATE TYPE my_crosstab_float8_5_cols AS (
    my_row_name text,
    my_category_1 float8,
    my_category_2 float8,
    my_category_3 float8,
    my_category_4 float8,
    my_category_5 float8
);

CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(text)
    RETURNS setof my_crosstab_float8_5_cols
    AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;
```

- Use `OUT` parameters to define the return type implicitly. The same example could also be done this way:

```
CREATE OR REPLACE FUNCTION crosstab_float8_5_cols(
    IN text,
    OUT my_row_name text,
    OUT my_category_1 float8,
    OUT my_category_2 float8,
    OUT my_category_3 float8,
    OUT my_category_4 float8,
    OUT my_category_5 float8)
  RETURNS setof record
  AS '$libdir/tablefunc','crosstab' LANGUAGE C STABLE STRICT;
```

F.37.1.4. `crosstab(text, text)`

```
crosstab(text source_sql, text category_sql)
```

The main limitation of the single-parameter form of `crosstab` is that it treats all values in a group alike, inserting each value into the first available column. If you want the value columns to correspond to specific categories of data, and some groups might not have data for some of the categories, that doesn't work well. The two-parameter form of `crosstab` handles this case by providing an explicit list of the categories corresponding to the output columns.

`source_sql` is a SQL statement that produces the source set of data. This statement must return one `row_name` column, one `category` column, and one `value` column. It may also have one or more "extra" columns. The `row_name` column must be first. The `category` and `value` columns must be the last two columns, in that order. Any columns between `row_name` and `category` are treated as "extra". The "extra" columns are expected to be the same for all rows with the same `row_name` value.

For example, `source_sql` might produce a set something like:

```
SELECT row_name, extra_col, cat, value FROM foo ORDER BY 1;

 row_name    extra_col   cat    value
----------+------------+-----+---------
  row1         extra1    cat1    val1
  row1         extra1    cat2    val2
  row1         extra1    cat4    val4
```

```
  row2         extra2    cat1    val5
  row2         extra2    cat2    val6
  row2         extra2    cat3    val7
  row2         extra2    cat4    val8
```

`category_sql` is a SQL statement that produces the set of categories. This statement must return only one column. It must produce at least one row, or an error will be generated. Also, it must not produce duplicate values, or an error will be generated. `category_sql` might be something like:

```
SELECT DISTINCT cat FROM foo ORDER BY 1;
    cat
  -------
    cat1
    cat2
    cat3
    cat4
```

The `crosstab` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM crosstab('...', '...')
    AS ct(row_name text, extra text, cat1 text, cat2 text, cat3 text, cat4 text);
```

This will produce a result something like:

```
                  <==  value  columns   ==>
row_name   extra   cat1   cat2   cat3   cat4
---------+-------+------+------+------+------
  row1     extra1  val1   val2          val4
  row2     extra2  val5   val6   val7   val8
```

The `FROM` clause must define the proper number of output columns of the proper data types. If there are *`N`* columns in the `source_sql` query's result, the first *`N`*-2 of them must match up with the first *`N`*-2 output columns. The remaining output columns must have the type of the last column of the `source_sql` query's result, and there must be exactly as many of them as there are rows in the `category_sql` query's result.

The `crosstab` function produces one output row for each consecutive group of input rows with the same `row_name` value. The output `row_name` column, plus any "extra" columns, are copied from the first row of the group. The output `value` columns are filled with the `value` fields from rows having matching `category` values. If a row's `category` does not match any output of the `category_sql` query, its `value` is ignored. Output columns whose matching category is not present in any input row of the group are filled with nulls.

In practice the `source_sql` query should always specify `ORDER BY 1` to ensure that values with the same `row_name` are brought together. However, ordering of the categories within a group is not important. Also, it is essential to be sure that the order of the `category_sql` query's output matches the specified output column order.

Here are two complete examples:

```
create table sales(year int, month int, qty int);
```

```
insert into sales values(2007, 1, 1000);
insert into sales values(2007, 2, 1500);
insert into sales values(2007, 7, 500);
insert into sales values(2007, 11, 1500);
insert into sales values(2007, 12, 2000);
insert into sales values(2008, 1, 1000);

select * from crosstab(
  'select year, month, qty from sales order by 1',
  'select m from generate_series(1,12) m'
) as (
  year int,
  "Jan" int,
  "Feb" int,
  "Mar" int,
  "Apr" int,
  "May" int,
  "Jun" int,
  "Jul" int,
  "Aug" int,
  "Sep" int,
  "Oct" int,
  "Nov" int,
  "Dec" int
);
 year | Jan  | Feb  | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov  | Dec
------+------+------+-----+-----+-----+-----+-----+-----+-----+-----+------+------
 2007 | 1000 | 1500 |     |     |     |     | 500 |     |     |     | 1500 | 2000
 2008 | 1000 |      |     |     |     |     |     |     |     |     |      |
(2 rows)

CREATE TABLE cth(rowid text, rowdt timestamp, attribute text, val text);
INSERT INTO cth VALUES('test1','01 March 2003','temperature','42');
INSERT INTO cth VALUES('test1','01 March 2003','test_result','PASS');
INSERT INTO cth VALUES('test1','01 March 2003','volts','2.6987');
INSERT INTO cth VALUES('test2','02 March 2003','temperature','53');
INSERT INTO cth VALUES('test2','02 March 2003','test_result','FAIL');
INSERT INTO cth VALUES('test2','02 March 2003','test_startdate','01 March 2003');
INSERT INTO cth VALUES('test2','02 March 2003','volts','3.1234');

SELECT * FROM crosstab
(
  'SELECT rowid, rowdt, attribute, val FROM cth ORDER BY 1',
  'SELECT DISTINCT attribute FROM cth ORDER BY 1'
)
AS
(
       rowid text,
       rowdt timestamp,
       temperature int4,
       test_result text,
       test_startdate timestamp,
       volts float8
);
 rowid |          rowdt           | temperature | test_result |      test_startdate
-------+--------------------------+-------------+-------------+--------------------------
 test1 | Sat Mar 01 00:00:00 2003 |          42 | PASS        |
```

```
 test2 | Sun Mar 02 00:00:00 2003 |          53 | FAIL        | Sat Mar 01 00:00:00 2003
(2 rows)
```

You can create predefined functions to avoid having to write out the result column names and types in each query. See the examples in the previous section. The underlying C function for this form of `crosstab` is named `crosstab_hash`.

F.37.1.5. `connectby`

```
connectby(text relname, text keyid_fld, text parent_keyid_fld
          [, text orderby_fld ], text start_with, int max_depth
          [, text branch_delim ])
```

The `connectby` function produces a display of hierarchical data that is stored in a table. The table must have a key field that uniquely identifies rows, and a parent-key field that references the parent (if any) of each row. `connectby` can display the sub-tree descending from any row.

Table F-29 explains the parameters.

Table F-29. `connectby` Parameters

Parameter	Description
`relname`	Name of the source relation
`keyid_fld`	Name of the key field
`parent_keyid_fld`	Name of the parent-key field
`orderby_fld`	Name of the field to order siblings by (optional)
`start_with`	Key value of the row to start at
`max_depth`	Maximum depth to descend to, or zero for unlimited depth
`branch_delim`	String to separate keys with in branch output (optional)

The key and parent-key fields can be any data type, but they must be the same type. Note that the `start_with` value must be entered as a text string, regardless of the type of the key field.

The `connectby` function is declared to return `setof record`, so the actual names and types of the output columns must be defined in the `FROM` clause of the calling `SELECT` statement, for example:

```
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid', 'pos', 'row2', 0, '~'
    AS t(keyid text, parent_keyid text, level int, branch text, pos int);
```

The first two output columns are used for the current row's key and its parent row's key; they must match the type of the table's key field. The third output column is the depth in the tree and must be of type `integer`. If a `branch_delim` parameter was given, the next output column is the branch display and must be of type `text`. Finally, if an `orderby_fld` parameter was given, the last output column is a serial number, and must be of type `integer`.

The "branch" output column shows the path of keys taken to reach the current row. The keys are separated by the specified `branch_delim` string. If no branch display is wanted, omit both the `branch_delim` parameter and the branch column in the output column list.

If the ordering of siblings of the same parent is important, include the `orderby_fld` parameter to

specify which field to order siblings by. This field can be of any sortable data type. The output column list must include a final integer serial-number column, if and only if `orderby_fld` is specified.

The parameters representing table and field names are copied as-is into the SQL queries that `connectby` generates internally. Therefore, include double quotes if the names are mixed-case or contain special characters. You may also need to schema-qualify the table name.

In large tables, performance will be poor unless there is an index on the parent-key field.

It is important that the `branch_delim` string not appear in any key values, else `connectby` may incorrectly report an infinite-recursion error. Note that if `branch_delim` is not provided, a default value of ~ is used for recursion detection purposes.

Here is an example:

```
CREATE TABLE connectby_tree(keyid text, parent_keyid text, pos int);

INSERT INTO connectby_tree VALUES('row1',NULL, 0);
INSERT INTO connectby_tree VALUES('row2','row1', 0);
INSERT INTO connectby_tree VALUES('row3','row1', 0);
INSERT INTO connectby_tree VALUES('row4','row2', 1);
INSERT INTO connectby_tree VALUES('row5','row2', 0);
INSERT INTO connectby_tree VALUES('row6','row4', 0);
INSERT INTO connectby_tree VALUES('row7','row3', 0);
INSERT INTO connectby_tree VALUES('row8','row6', 0);
INSERT INTO connectby_tree VALUES('row9','row5', 0);

-- with branch, without orderby_fld (order of results is not guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid', 'row2', 0, '~')
 AS t(keyid text, parent_keyid text, level int, branch text);
 keyid | parent_keyid | level |       branch
-------+--------------+-------+--------------------
 row2  |              |     0 | row2
 row4  | row2         |     1 | row2~row4
 row6  | row4         |     2 | row2~row4~row6
 row8  | row6         |     3 | row2~row4~row6~row8
 row5  | row2         |     1 | row2~row5
 row9  | row5         |     2 | row2~row5~row9
(6 rows)

-- without branch, without orderby_fld (order of results is not guaranteed)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid', 'row2', 0)
 AS t(keyid text, parent_keyid text, level int);
 keyid | parent_keyid | level
-------+--------------+-------
 row2  |              |     0
 row4  | row2         |     1
 row6  | row4         |     2
 row8  | row6         |     3
 row5  | row2         |     1
 row9  | row5         |     2
(6 rows)

-- with branch, with orderby_fld (notice that row5 comes before row4)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid', 'pos', 'row2', 0, '~'
 AS t(keyid text, parent_keyid text, level int, branch text, pos int);
 keyid | parent_keyid | level |       branch        | pos
-------+--------------+-------+---------------------+-----
 row2  |              |     0 | row2                |   1
```

```
 row5  | row2         |     1 | row2~row5           |   2
 row9  | row5         |     2 | row2~row5~row9      |   3
 row4  | row2         |     1 | row2~row4           |   4
 row6  | row4         |     2 | row2~row4~row6      |   5
 row8  | row6         |     3 | row2~row4~row6~row8 |   6
(6 rows)

-- without branch, with orderby_fld (notice that row5 comes before row4)
SELECT * FROM connectby('connectby_tree', 'keyid', 'parent_keyid', 'pos', 'row2', 0)
 AS t(keyid text, parent_keyid text, level int, pos int);
 keyid | parent_keyid | level | pos
-------+--------------+-------+-----
 row2  |              |     0 |   1
 row5  | row2         |     1 |   2
 row9  | row5         |     2 |   3
 row4  | row2         |     1 |   4
 row6  | row4         |     2 |   5
 row8  | row6         |     3 |   6
(6 rows)
```

F.37.2. Author

Joe Conway

F.38. tcn

The `tcn` module provides a trigger function that notifies listeners of changes to any table on which it is attached. It must be used as an `AFTER` trigger `FOR EACH ROW`.

Only one parameter may be supplied to the function in a `CREATE TRIGGER` statement, and that is optional. If supplied it will be used for the channel name for the notifications. If omitted `tcn` will be used for the channel name.

The payload of the notifications consists of the table name, a letter to indicate which type of operation was performed, and column name/value pairs for primary key columns. Each part is separated from the next by a comma. For ease of parsing using regular expressions, table and column names are always wrapped in double quotes, and data values are always wrapped in single quotes. Embedded quotes are doubled.

A brief example of using the extension follows.

```
test=# create table tcndata
test-#   (
test(#     a int not null,
test(#     b date not null,
test(#     c text,
test(#     primary key (a, b)
test(#   );
CREATE TABLE
test=# create trigger tcndata_tcn_trigger
test-#   after insert or update or delete on tcndata
```

```
test-#   for each row execute procedure triggered_change_notification();
CREATE TRIGGER
test=# listen tcn;
LISTEN
test=# insert into tcndata values (1, date '2012-12-22', 'one'),
test-#                            (1, date '2012-12-23', 'another'),
test-#                            (2, date '2012-12-23', 'two');
INSERT 0 3
Asynchronous notification "tcn" with payload ""tcndata",I,"a"='1',"b"='2012-12-22'" rece
Asynchronous notification "tcn" with payload ""tcndata",I,"a"='1',"b"='2012-12-23'" rece
Asynchronous notification "tcn" with payload ""tcndata",I,"a"='2',"b"='2012-12-23'" rece
test=# update tcndata set c = 'uno' where a = 1;
UPDATE 2
Asynchronous notification "tcn" with payload ""tcndata",U,"a"='1',"b"='2012-12-22'" rece
Asynchronous notification "tcn" with payload ""tcndata",U,"a"='1',"b"='2012-12-23'" rece
test=# delete from tcndata where a = 1 and b = date '2012-12-22';
DELETE 1
Asynchronous notification "tcn" with payload ""tcndata",D,"a"='1',"b"='2012-12-22'" rece
```

F.39. test_decoding

`test_decoding` is an example of a logical decoding output plugin. It doesn't do anything especially useful, but can serve as a starting point for developing your own decoder.

`test_decoding` receives WAL through the logical decoding mechanism and decodes it into text representations of the operations performed.

Typical output from this plugin, used over the SQL logical decoding interface, might be:

```
postgres=# SELECT * FROM pg_logical_slot_get_changes('test_slot', NULL, NULL, 'include-x
 location  | xid |                       data
-----------+-----+--------------------------------------------------
 0/16D30F8 | 691 | BEGIN
 0/16D32A0 | 691 | table public.data: INSERT: id[int4]:2 data[text]:'arg'
 0/16D32A0 | 691 | table public.data: INSERT: id[int4]:3 data[text]:'demo'
 0/16D32A0 | 691 | COMMIT
 0/16D32D8 | 692 | BEGIN
 0/16D3398 | 692 | table public.data: DELETE: id[int4]:2
 0/16D3398 | 692 | table public.data: DELETE: id[int4]:3
 0/16D3398 | 692 | COMMIT
(8 rows)
```

F.40. test_parser

`test_parser` is an example of a custom parser for full-text search. It doesn't do anything especially useful, but can serve as a starting point for developing your own parser.

`test_parser` recognizes words separated by white space, and returns just two token types:

```
mydb=# SELECT * FROM ts_token_type('testparser');
```

```
 tokid | alias |  description
-------+-------+--------------
     3 | word  | Word
    12 | blank | Space symbols
(2 rows)
```

These token numbers have been chosen to be compatible with the default parser's numbering. This allows us to use its `headline()` function, thus keeping the example simple.

F.40.1. Usage

Installing the `test_parser` extension creates a text search parser `testparser`. It has no user-configurable parameters.

You can test the parser with, for example,

```
mydb=# SELECT * FROM ts_parse('testparser', 'That"s my first own parser');
 tokid | token
-------+--------
     3 | That's
    12 |
     3 | my
    12 |
     3 | first
    12 |
     3 | own
    12 |
     3 | parser
```

Real-world use requires setting up a text search configuration that uses the parser. For example,

```
mydb=# CREATE TEXT SEARCH CONFIGURATION testcfg ( PARSER = testparser );
CREATE TEXT SEARCH CONFIGURATION

mydb=# ALTER TEXT SEARCH CONFIGURATION testcfg
mydb-#   ADD MAPPING FOR word WITH english_stem;
ALTER TEXT SEARCH CONFIGURATION

mydb=#  SELECT to_tsvector('testcfg', 'That"s my first own parser');
          to_tsvector
-------------------------------
 'that':1 'first':3 'parser':5
(1 row)

mydb=# SELECT ts_headline('testcfg', 'Supernovae stars are the brightest phenomena in ga
mydb(#                    to_tsquery('testcfg', 'star'));
                         ts_headline
------------------------------------------------------------------
 Supernovae <b>stars</b> are the brightest phenomena in galaxies
(1 row)
```

F.41. test_shm_mq

`test_shm_mq` is an example of how to use dynamic shared memory and the shared memory message queue facilities to coordinate a user backend with the efforts of one or more background workers. It is not intended to do anything useful on its own; rather, it is a demonstration of how these facilities can be used, and a unit test of those facilities.

The function is this extension send the same message repeatedly through a loop of processes. The message payload, the size of the message queue through which it is sent, and the number of processes in the loop are configurable. At the end, the message may be verified to ensure that it has not been corrupted in transmission.

F.41.1. Functions

```
test_shm_mq(queue_size int8, message text,
            repeat_count int4 default 1, num_workers int4 default 1)
    RETURNS void
```

This function sends and receives messages synchronously. The user backend sends the provided message to the first background worker using a message queue of the given size. The first background worker sends the message to the second background worker, if the number of workers is greater than one, and so forth. Eventually, the last background worker sends the message back to the user backend. If the repeat count is greater than one, the user backend then sends the message back to the first worker. Once the message has been sent and received by all the coordinating processes a number of times equal to the repeat count, the user backend verifies that the message finally received matches the one originally sent and throws an error if not.

```
test_shm_mq_pipelined(queue_size int8, message text,
                      repeat_count int4 default 1, num_workers int4 default 1,
                      verify bool default true)
    RETURNS void
```

This function sends the same message multiple times, as specified by the repeat count, to the first background worker using a queue of the given size. These messages are then forwarded to each background worker in turn, in each case using a queue of the given size. Finally, the last background worker sends the messages back to the user backend. The user backend uses non-blocking sends and receives, so that it may begin receiving copies of the message before it has finished sending all copies of the message. The `verify` argument controls whether or not the received copies are checked against the message that was sent. (This takes nontrivial time so it may be useful to disable it for benchmarking purposes.)

F.42. tsearch2

The tsearch2 module provides backwards-compatible text search functionality for applications that used tsearch2 before text searching was integrated into core PostgreSQL in release 8.3.

F.42.1. Portability Issues

Although the built-in text search features were based on tsearch2 and are largely similar to it, there are numerous small differences that will create portability issues for existing applications:

- Some functions' names were changed, for example `rank` to `ts_rank`. The replacement `tsearch2` module provides aliases having the old names.
- The built-in text search data types and functions all exist within the system schema `pg_catalog`. In an installation using tsearch2, these objects would usually have been in the `public` schema, though some users chose to place them in a separate schema of their own. Explicitly schema-qualified references to the objects will therefore fail in either case. The replacement `tsearch2` module provides alias objects that are stored in `public` (or another schema if necessary) so that such references will still work.
- There is no concept of a "current parser" or "current dictionary" in the built-in text search features, only of a current search configuration (set by the `default_text_search_config` parameter). While the current parser and current dictionary were used only by functions intended for debugging, this might still pose a porting obstacle in some cases. The replacement `tsearch2` module emulates these additional state variables and provides backwards-compatible functions for setting and retrieving them.

There are some issues that are not addressed by the replacement `tsearch2` module, and will therefore require application code changes in any case:

- The old `tsearch2` trigger function allowed items in its argument list to be names of functions to be invoked on the text data before it was converted to `tsvector` format. This was removed as being a security hole, since it was not possible to guarantee that the function invoked was the one intended. The recommended approach if the data must be massaged before being indexed is to write a custom trigger that does the work for itself.
- Text search configuration information has been moved into core system catalogs that are noticeably different from the tables used by tsearch2. Any applications that examined or modified those tables will need adjustment.
- If an application used any custom text search configurations, those will need to be set up in the core catalogs using the new text search configuration SQL commands. The replacement `tsearch2` module offers a little bit of support for this by making it possible to load an old set of tsearch2 configuration tables into PostgreSQL 8.3. (Without the module, it is not possible to load the configuration data because values in the `regprocedure` columns cannot be resolved to functions.) While those configuration tables won't actually *do* anything, at least their contents will be available to be consulted while setting up an equivalent custom configuration in 8.3.
- The old `reset_tsearch()` and `get_covers()` functions are not supported.
- The replacement `tsearch2` module does not define any alias operators, relying entirely on the built-in ones. This would only pose an issue if an application used explicitly schema-qualified operator names, which is very uncommon.

F.42.2. Converting a pre-8.3 Installation

The recommended way to update a pre-8.3 installation that uses tsearch2 is:

1. Make a dump from the old installation in the usual way, but be sure not to use `-c` (`--clean`) option of pg_dump or pg_dumpall.
2. In the new installation, create empty database(s) and install the replacement `tsearch2` module into each database that will use text search. This must be done *before* loading the dump data! If your old installation had the tsearch2 objects in a schema other than `public`, be sure to adjust the `CREATE EXTENSION` command so that the replacement objects are created in that same schema.

3. Load the dump data. There will be quite a few errors reported due to failure to recreate the original tsearch2 objects. These errors can be ignored, but this means you cannot restore the dump in a single transaction (eg, you cannot use pg_restore's `-1` switch).
4. Examine the contents of the restored tsearch2 configuration tables (`pg_ts_cfg` and so on), and create equivalent built-in text search configurations as needed. You may drop the old configuration tables once you've extracted all the useful information from them.
5. Test your application.

At a later time you may wish to rename application references to the alias text search objects, so that you can eventually uninstall the replacement `tsearch2` module.

F.42.3. References

Tsearch2 Development Site http://www.sai.msu.su/~megera/postgres/gist/tsearch/V2/

F.43. unaccent

`unaccent` is a text search dictionary that removes accents (diacritic signs) from lexemes. It's a filtering dictionary, which means its output is always passed to the next dictionary (if any), unlike the normal behavior of dictionaries. This allows accent-insensitive processing for full text search.

The current implementation of `unaccent` cannot be used as a normalizing dictionary for the `thesaurus` dictionary.

F.43.1. Configuration

An `unaccent` dictionary accepts the following options:

- `RULES` is the base name of the file containing the list of translation rules. This file must be stored in `$SHAREDIR/tsearch_data/` (where `$SHAREDIR` means the PostgreSQL installation's shared-data directory). Its name must end in `.rules` (which is not to be included in the `RULES` parameter).

The rules file has the following format:

- Each line represents a pair, consisting of a character with accent followed by a character without accent. The first is translated into the second. For example,

```
À       A
Á       A
Â       A
Ã       A
Ä       A
Å       A
Æ       A
```

A more complete example, which is directly useful for most European languages, can be found in `unaccent.rules`, which is installed in `$SHAREDIR/tsearch_data/` when the `unaccent` module is installed.

F.43.2. Usage

Installing the unaccent extension creates a text search template unaccent and a dictionary unaccent based on it. The unaccent dictionary has the default parameter setting RULES='unaccent', which makes it immediately usable with the standard unaccent.rules file. If you wish, you can alter the parameter, for example

```
mydb=# ALTER TEXT SEARCH DICTIONARY unaccent (RULES='my_rules');
```

or create new dictionaries based on the template.

To test the dictionary, you can try:

```
mydb=# select ts_lexize('unaccent','Hôtel');
 ts_lexize
-----------
 {Hotel}
(1 row)
```

Here is an example showing how to insert the unaccent dictionary into a text search configuration:

```
mydb=# CREATE TEXT SEARCH CONFIGURATION fr ( COPY = french );
mydb=# ALTER TEXT SEARCH CONFIGURATION fr
        ALTER MAPPING FOR hword, hword_part, word
        WITH unaccent, french_stem;
mydb=# select to_tsvector('fr','Hôtels de la Mer');
    to_tsvector
-------------------
 'hotel':1 'mer':4
(1 row)

mydb=# select to_tsvector('fr','Hôtel de la Mer') @@ to_tsquery('fr','Hotels');
 ?column?
----------
 t
(1 row)

mydb=# select ts_headline('fr','Hôtel de la Mer',to_tsquery('fr','Hotels'));
      ts_headline
------------------------
 <b>Hôtel</b> de la Mer
(1 row)
```

F.43.3. Functions

The unaccent() function removes accents (diacritic signs) from a given string. Basically, it's a wrapper around the unaccent dictionary, but it can be used outside normal text search contexts.

```
unaccent([dictionary, ] string) returns text
```

For example:

```
SELECT unaccent('unaccent', 'Hôtel');
```

```
SELECT unaccent('Hôtel');
```

F.44. uuid-ossp

The `uuid-ossp` module provides functions to generate universally unique identifiers (UUIDs) using one of several standard algorithms. There are also functions to produce certain special UUID constants.

F.44.1. `uuid-ossp` Functions

Table F-30 shows the functions available to generate UUIDs. The relevant standards ITU-T Rec. X.667, ISO/IEC 9834-8:2005, and RFC 4122 specify four algorithms for generating UUIDs, identified by the version numbers 1, 3, 4, and 5. (There is no version 2 algorithm.) Each of these algorithms could be suitable for a different set of applications.

Table F-30. Functions for UUID Generation

Function	Description
`uuid_generate_v1()`	This function generates a version 1 UUID. This involves the MAC address of the computer and a time stamp. Note that UUIDs of this kind reveal the identity of the computer that created the identifier and the time at which it did so, which might make it unsuitable for certain security-sensitive applications.
`uuid_generate_v1mc()`	This function generates a version 1 UUID but uses a random multicast MAC address instead of the real MAC address of the computer.
`uuid_generate_v3(namespace uuid, name text)`	This function generates a version 3 UUID in the given namespace using the specified input name. The namespace should be one of the special constants produced by the `uuid_ns_*()` functions shown in Table F-31. (It could be any UUID in theory.) The name is an identifier in the selected namespace. For example: `SELECT uuid_generate_v3(uuid_ns_url(), 'http://www` The name parameter will be MD5-hashed, so the cleartext cannot be derived from the generated UUID. The generation of UUIDs by this method has no random or environment-dependent element and is therefore reproducible.

Function	Description
`uuid_generate_v4()`	This function generates a version 4 UUID, which is derived entirely from random numbers.
`uuid_generate_v5(namespace uuid, name text)`	This function generates a version 5 UUID, which works like a version 3 UUID except that SHA-1 is used as a hashing method. Version 5 should be preferred over version 3 because SHA-1 is thought to be more secure than MD5.

Table F-31. Functions Returning UUID Constants

`uuid_nil()`	A "nil" UUID constant, which does not occur as a real UUID.
`uuid_ns_dns()`	Constant designating the DNS namespace for UUIDs.
`uuid_ns_url()`	Constant designating the URL namespace for UUIDs.
`uuid_ns_oid()`	Constant designating the ISO object identifier (OID) namespace for UUIDs. (This pertains to ASN.1 OIDs, which are unrelated to the OIDs used in PostgreSQL.)
`uuid_ns_x500()`	Constant designating the X.500 distinguished name (DN) namespace for UUIDs.

F.44.2. Building `uuid-ossp`

Historically this module depended on the OSSP UUID library, which accounts for the module's name. While the OSSP UUID library can still be found at http://www.ossp.org/pkg/lib/uuid/, it is not well maintained, and is becoming increasingly difficult to port to newer platforms. `uuid-ossp` can now be built without the OSSP library on some platforms. On FreeBSD, NetBSD, and some other BSD-derived platforms, suitable UUID creation functions are included in the core `libc` library. On Linux, OS X, and some other platforms, suitable functions are provided in the `libuuid` library, which originally came from the `e2fsprogs` project (though on modern Linux it is considered part of `util-linux-ng`). When invoking `configure`, specify `--with-uuid=bsd` to use the BSD functions, or `--with-uuid=e2fs` to use `e2fsprogs`' `libuuid`, or `--with-uuid=ossp` to use the OSSP UUID library. More than one of these libraries might be available on a particular machine, so `configure` does not automatically choose one.

> **Note:** If you only need randomly-generated (version 4) UUIDs, consider using the `gen_random_uuid()` function from the pgcrypto module instead.

F.44.3. Author

Peter Eisentraut <`peter_e@gmx.net`>

F.45. xml2

The xml2 module provides XPath querying and XSLT functionality.

F.45.1. Deprecation Notice

From PostgreSQL 8.3 on, there is XML-related functionality based on the SQL/XML standard in the core server. That functionality covers XML syntax checking and XPath queries, which is what this module does, and more, but the API is not at all compatible. It is planned that this module will be removed in a future version of PostgreSQL in favor of the newer standard API, so you are encouraged to try converting your applications. If you find that some of the functionality of this module is not available in an adequate form with the newer API, please explain your issue to <pgsql-hackers@postgresql.org> so that the deficiency can be addressed.

F.45.2. Description of Functions

Table F-32 shows the functions provided by this module. These functions provide straightforward XML parsing and XPath queries. All arguments are of type text, so for brevity that is not shown.

Table F-32. Functions

Function	Returns	Description
xml_is_well_formed(document)	bool	This parses the document text in its parameter and returns true if the document is well-formed XML. (Note: before PostgreSQL 8.2, this function was called xml_valid(). That is the wrong name since validity and well-formedness have different meanings in XML. The old name is still available, but is deprecated.)
xpath_string(document, query)	text	These functions evaluate the XPath query on the supplied document, and cast the result to the specified type.
xpath_number(document, query)	float4	
xpath_bool(document, query)	bool	

Function	Returns	Description
`xpath_nodeset(document, query, toptag, itemtag)`	`text`	This evaluates query on document and wraps the result in XML tags. If the result is multivalued, the output will look like: `<toptag> <itemtag>Value 1 which could be an XM <itemtag>Value 2....</itemtag> </toptag>` If either `toptag` or `itemtag` is an empty string, the relevant tag is omitted.
`xpath_nodeset(document, query)`	`text`	Like `xpath_nodeset(document, query, toptag, itemtag)` but result omits both tags.
`xpath_nodeset(document, query, itemtag)`	`text`	Like `xpath_nodeset(document, query, toptag, itemtag)` but result omits `toptag`.
`xpath_list(document, query, separator)`	`text`	This function returns multiple values separated by the specified separator, for example `Value 1,Value 2,Value 3` if separator is `,`.
`xpath_list(document, query)`	`text`	This is a wrapper for the above function that uses `,` as the separator.

F.45.3. `xpath_table`

```
xpath_table(text key, text document, text relation, text xpaths, text criteria) returns
```

`xpath_table` is a table function that evaluates a set of XPath queries on each of a set of documents and returns the results as a table. The primary key field from the original document table is returned as the first column of the result so that the result set can readily be used in joins. The parameters are described in Table F-33.

Table F-33. `xpath_table` Parameters

Parameter	Description
`key`	the name of the "key" field — this is just a field to be used as the first column of the output table, i.e., it identifies the record from which each output row came (see note below about multiple values)

Parameter	Description
`document`	the name of the field containing the XML document
`relation`	the name of the table or view containing the documents
`xpaths`	one or more XPath expressions, separated by `|`
`criteria`	the contents of the WHERE clause. This cannot be omitted, so use `true` or `1=1` if you want to process all the rows in the relation

These parameters (except the XPath strings) are just substituted into a plain SQL SELECT statement, so you have some flexibility — the statement is

```
SELECT <key>, <document> FROM <relation> WHERE <criteria>
```

so those parameters can be *anything* valid in those particular locations. The result from this SELECT needs to return exactly two columns (which it will unless you try to list multiple fields for key or document). Beware that this simplistic approach requires that you validate any user-supplied values to avoid SQL injection attacks.

The function has to be used in a `FROM` expression, with an `AS` clause to specify the output columns; for example

```
SELECT * FROM
xpath_table('article_id',
            'article_xml',
            'articles',
            '/article/author|/article/pages|/article/title',
            'date_entered > "2003-01-01" ')
AS t(article_id integer, author text, page_count integer, title text);
```

The `AS` clause defines the names and types of the columns in the output table. The first is the "key" field and the rest correspond to the XPath queries. If there are more XPath queries than result columns, the extra queries will be ignored. If there are more result columns than XPath queries, the extra columns will be NULL.

Notice that this example defines the `page_count` result column as an integer. The function deals internally with string representations, so when you say you want an integer in the output, it will take the string representation of the XPath result and use PostgreSQL input functions to transform it into an integer (or whatever type the `AS` clause requests). An error will result if it can't do this — for example if the result is empty — so you may wish to just stick to `text` as the column type if you think your data has any problems.

The calling `SELECT` statement doesn't necessarily have be just `SELECT *` — it can reference the output columns by name or join them to other tables. The function produces a virtual table with which you can perform any operation you wish (e.g. aggregation, joining, sorting etc). So we could also have:

```
SELECT t.title, p.fullname, p.email
FROM xpath_table('article_id', 'article_xml', 'articles',
                 '/article/title|/article/author/@id',
                 'xpath_string(article_xml,"/article/@date") > "2003-03-20" ')
       AS t(article_id integer, title text, author_id integer),
     tblPeopleInfo AS p
WHERE t.author_id = p.person_id;
```

as a more complicated example. Of course, you could wrap all of this in a view for convenience.

F.45.3.1. Multivalued Results

The `xpath_table` function assumes that the results of each XPath query might be multivalued, so the number of rows returned by the function may not be the same as the number of input documents. The first row returned contains the first result from each query, the second row the second result from each query. If one of the queries has fewer values than the others, null values will be returned instead.

In some cases, a user will know that a given XPath query will return only a single result (perhaps a unique document identifier) — if used alongside an XPath query returning multiple results, the single-valued result will appear only on the first row of the result. The solution to this is to use the key field as part of a join against a simpler XPath query. As an example:

```
CREATE TABLE test (
    id int PRIMARY KEY,
    xml text
);

INSERT INTO test VALUES (1, '<doc num="C1">
<line num="L1"><a>1</a><b>2</b><c>3</c></line>
<line num="L2"><a>11</a><b>22</b><c>33</c></line>
</doc>');

INSERT INTO test VALUES (2, '<doc num="C2">
<line num="L1"><a>111</a><b>222</b><c>333</c></line>
<line num="L2"><a>111</a><b>222</b><c>333</c></line>
</doc>');

SELECT * FROM
  xpath_table('id','xml','test',
              '/doc/@num|/doc/line/@num|/doc/line/a|/doc/line/b|/doc/line/c',
              'true')
  AS t(id int, doc_num varchar(10), line_num varchar(10), val1 int, val2 int, val3 int)
WHERE id = 1 ORDER BY doc_num, line_num

 id | doc_num | line_num | val1 | val2 | val3
----+---------+----------+------+------+------
  1 | C1      | L1       |    1 |    2 |    3
  1 |         | L2       |   11 |   22 |   33
```

To get `doc_num` on every line, the solution is to use two invocations of `xpath_table` and join the results:

```
SELECT t.*,i.doc_num FROM
  xpath_table('id', 'xml', 'test',
              '/doc/line/@num|/doc/line/a|/doc/line/b|/doc/line/c',
              'true')
    AS t(id int, line_num varchar(10), val1 int, val2 int, val3 int),
  xpath_table('id', 'xml', 'test', '/doc/@num', 'true')
    AS i(id int, doc_num varchar(10))
WHERE i.id=t.id AND i.id=1
ORDER BY doc_num, line_num;

 id | line_num | val1 | val2 | val3 | doc_num
```

```
----+----------+------+------+------+---------
  1 | L1       |    1 |    2 |    3 | C1
  1 | L2       |   11 |   22 |   33 | C1
(2 rows)
```

F.45.4. XSLT Functions

The following functions are available if libxslt is installed:

F.45.4.1. `xslt_process`

```
xslt_process(text document, text stylesheet, text paramlist) returns text
```

This function applies the XSL stylesheet to the document and returns the transformed result. The `paramlist` is a list of parameter assignments to be used in the transformation, specified in the form `a=1,b=2`. Note that the parameter parsing is very simple-minded: parameter values cannot contain commas!

There is also a two-parameter version of `xslt_process` which does not pass any parameters to the transformation.

F.45.5. Author

John Gray <jgray@azuli.co.uk>

Development of this module was sponsored by Torchbox Ltd. (www.torchbox.com). It has the same BSD license as PostgreSQL.

Appendix G. Additional Supplied Programs

This appendix and the previous one contain information regarding the modules that can be found in the `contrib` directory of the PostgreSQL distribution. See Appendix F for more information about the `contrib` section in general and server extensions and plug-ins found in `contrib` specifically.

This appendix covers utility programs found in `contrib`. Once installed, either from source or a packaging system, they are found in the `bin` directory of the PostgreSQL installation and can be used like any other program.

G.1. Client Applications

This section covers PostgreSQL client applications in `contrib`. They can be run from anywhere, independent of where the database server resides. See also Reference II, *PostgreSQL Client Applications* for information about client applications that part of the core PostgreSQL distribution.

oid2name

Name

`oid2name` — resolve OIDs and file nodes in a PostgreSQL data directory

Synopsis

`oid2name` [*option*...]

Description

oid2name is a utility program that helps administrators to examine the file structure used by PostgreSQL. To make use of it, you need to be familiar with the database file structure, which is described in Chapter 59.

> **Note:** The name "oid2name" is historical, and is actually rather misleading, since most of the time when you use it, you will really be concerned with tables' filenode numbers (which are the file names visible in the database directories). Be sure you understand the difference between table OIDs and table filenodes!

oid2name connects to a target database and extracts OID, filenode, and/or table name information. You can also have it show database OIDs or tablespace OIDs.

Options

oid2name accepts the following command-line arguments:

`-f` *`filenode`*

show info for table with filenode *`filenode`*

`-i`

include indexes and sequences in the listing

`-o` *`oid`*

show info for table with OID *`oid`*

`-q`

omit headers (useful for scripting)

`-s`

show tablespace OIDs

`-S`

include system objects (those in `information_schema`, `pg_toast` and `pg_catalog` schemas)

`-t` *`tablename_pattern`*

show info for table(s) matching *`tablename_pattern`*

`-V`
`--version`

Print the oid2name version and exit.

`-x`

display more information about each object shown: tablespace name, schema name, and OID

`-?`
`--help`

Show help about oid2name command line arguments, and exit.

oid2name also accepts the following command-line arguments for connection parameters:

`-d` *`database`*

database to connect to

`-H` *`host`*

database server's host

`-p` *`port`*

database server's port

`-U` *`username`*

user name to connect as

`-P` *`password`*

password (deprecated — putting this on the command line is a security hazard)

To display specific tables, select which tables to show by using `-o`, `-f` and/or `-t`. `-o` takes an OID, `-f` takes a filenode, and `-t` takes a table name (actually, it's a `LIKE` pattern, so you can use things like `foo%`). You can use as many of these options as you like, and the listing will include all objects matched by any of the options. But note that these options can only show objects in the database given by `-d`.

If you don't give any of `-o`, `-f` or `-t`, but do give `-d`, it will list all tables in the database named by `-d`. In this mode, the `-S` and `-i` options control what gets listed.

If you don't give `-d` either, it will show a listing of database OIDs. Alternatively you can give `-s` to get a tablespace listing.

Notes

oid2name requires a running database server with non-corrupt system catalogs. It is therefore of only limited use for recovering from catastrophic database corruption situations.

Examples

```
$ # what's in this database server, anyway?
$ oid2name
All databases:
    Oid  Database Name  Tablespace
----------------------------------
  17228       alvherre  pg_default
  17255     regression  pg_default
  17227      template0  pg_default
      1      template1  pg_default

$ oid2name -s
All tablespaces:
     Oid  Tablespace Name
-------------------------
    1663       pg_default
    1664        pg_global
  155151         fastdisk
  155152          bigdisk

$ # OK, let's look into database alvherre
$ cd $PGDATA/base/17228

$ # get top 10 db objects in the default tablespace, ordered by size
$ ls -lS * | head -10
-rw-------  1 alvherre alvherre 136536064 sep 14 09:51 155173
-rw-------  1 alvherre alvherre  17965056 sep 14 09:51 1155291
-rw-------  1 alvherre alvherre   1204224 sep 14 09:51 16717
-rw-------  1 alvherre alvherre    581632 sep  6 17:51 1255
-rw-------  1 alvherre alvherre    237568 sep 14 09:50 16674
-rw-------  1 alvherre alvherre    212992 sep 14 09:51 1249
-rw-------  1 alvherre alvherre    204800 sep 14 09:51 16684
```

```
-rw-------  1 alvherre alvherre    196608 sep 14 09:50 16700
-rw-------  1 alvherre alvherre    163840 sep 14 09:50 16699
-rw-------  1 alvherre alvherre    122880 sep  6 17:51 16751

$ # I wonder what file 155173 is ...
$ oid2name -d alvherre -f 155173
From database "alvherre":
  Filenode  Table Name
----------------------
    155173    accounts

$ # you can ask for more than one object
$ oid2name -d alvherre -f 155173 -f 1155291
From database "alvherre":
  Filenode     Table Name
-------------------------
    155173       accounts
   1155291  accounts_pkey

$ # you can mix the options, and get more details with -x
$ oid2name -d alvherre -t accounts -f 1155291 -x
From database "alvherre":
  Filenode     Table Name      Oid  Schema  Tablespace
-----------------------------------------------------
    155173       accounts   155173  public  pg_default
   1155291  accounts_pkey  1155291  public  pg_default

$ # show disk space for every db object
$ du [0-9]* |
> while read SIZE FILENODE
> do
>   echo "$SIZE       `oid2name -q -d alvherre -i -f $FILENODE`"
> done
16            1155287  branches_pkey
16            1155289  tellers_pkey
17561            1155291  accounts_pkey
...

$ # same, but sort by size
$ du [0-9]* | sort -rn | while read SIZE FN
> do
>   echo "$SIZE   `oid2name -q -d alvherre -f $FN`"
> done
133466             155173    accounts
17561            1155291  accounts_pkey
1177              16717  pg_proc_proname_args_nsp_index
...

$ # If you want to see what's in tablespaces, use the pg_tblspc directory
$ cd $PGDATA/pg_tblspc
$ oid2name -s
All tablespaces:
     Oid  Tablespace Name
-------------------------
    1663       pg_default
    1664        pg_global
  155151         fastdisk
```

```
  155152          bigdisk

$ # what databases have objects in tablespace "fastdisk"?
$ ls -d 155151/*
155151/17228/  155151/PG_VERSION

$ # Oh, what was database 17228 again?
$ oid2name
All databases:
    Oid  Database Name  Tablespace
----------------------------------
  17228       alvherre  pg_default
  17255     regression  pg_default
  17227      template0  pg_default
      1      template1  pg_default

$ # Let's see what objects does this database have in the tablespace.
$ cd 155151/17228
$ ls -l
total 0
-rw-------  1 postgres postgres 0 sep 13 23:20 155156

$ # OK, this is a pretty small table ... but which one is it?
$ oid2name -d alvherre -f 155156
From database "alvherre":
  Filenode  Table Name
----------------------
    155156         foo
```

Author

B. Palmer <bpalmer@crimelabs.net>

pgbench

Name

pgbench — run a benchmark test on PostgreSQL

Synopsis

pgbench -i [*option*...] [*dbname*]

pgbench [*option*...] [*dbname*]

Description

pgbench is a simple program for running benchmark tests on PostgreSQL. It runs the same sequence of SQL commands over and over, possibly in multiple concurrent database sessions, and then calculates the average transaction rate (transactions per second). By default, pgbench tests a scenario that is loosely based on TPC-B, involving five SELECT, UPDATE, and INSERT commands per transaction. However, it is easy to test other cases by writing your own transaction script files.

Typical output from pgbench looks like:

```
transaction type: TPC-B (sort of)
scaling factor: 10
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
tps = 85.184871 (including connections establishing)
tps = 85.296346 (excluding connections establishing)
```

The first six lines report some of the most important parameter settings. The next line reports the number of transactions completed and intended (the latter being just the product of number of clients and number of transactions per client); these will be equal unless the run failed before completion. (In -T mode, only the actual number of transactions is printed.) The last two lines report the number of transactions per second, figured with and without counting the time to start database sessions.

The default TPC-B-like transaction test requires specific tables to be set up beforehand. pgbench should be invoked with the -i (initialize) option to create and populate these tables. (When you are testing a custom script, you don't need this step, but will instead need to do whatever setup your test needs.) Initialization looks like:

```
pgbench -i [ other-options ] dbname
```

where *dbname* is the name of the already-created database to test in. (You may also need -h, -p, and/or -U options to specify how to connect to the database server.)

> **Caution**
>
> `pgbench -i` creates four tables `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`, destroying any existing tables of these names. Be very careful to use another database if you have tables having these names!

At the default "scale factor" of 1, the tables initially contain this many rows:

```
table                   # of rows
---------------------------------
pgbench_branches        1
pgbench_tellers         10
pgbench_accounts        100000
pgbench_history         0
```

You can (and, for most purposes, probably should) increase the number of rows by using the `-s` (scale factor) option. The `-F` (fillfactor) option might also be used at this point.

Once you have done the necessary setup, you can run your benchmark with a command that doesn't include `-i`, that is

```
pgbench [ options ] dbname
```

In nearly all cases, you'll need some options to make a useful test. The most important options are `-c` (number of clients), `-t` (number of transactions), `-T` (time limit), and `-f` (specify a custom script file). See below for a full list.

Options

The following is divided into three subsections: Different options are used during database initialization and while running benchmarks, some options are useful in both cases.

Initialization Options

pgbench accepts the following command-line initialization arguments:

`-i`
`--initialize`

Required to invoke initialization mode.

`-F` *`fillfactor`*
`--fillfactor=`*`fillfactor`*

Create the `pgbench_accounts`, `pgbench_tellers` and `pgbench_branches` tables with the given fillfactor. Default is 100.

`-n`
`--no-vacuum`

Perform no vacuuming after initialization.

`-q`
`--quiet`

Switch logging to quiet mode, producing only one progress message per 5 seconds. The default logging prints one message each 100000 rows, which often outputs many lines per second (especially on good hardware).

`-s` *`scale_factor`*
`--scale=`*`scale_factor`*

Multiply the number of rows generated by the scale factor. For example, `-s 100` will create 10,000,000 rows in the `pgbench_accounts` table. Default is 1. When the scale is 20,000 or larger, the columns used to hold account identifiers (`aid` columns) will switch to using larger integers (`bigint`), in order to be big enough to hold the range of account identifiers.

`--foreign-keys`

Create foreign key constraints between the standard tables.

`--index-tablespace=`*`index_tablespace`*

Create indexes in the specified tablespace, rather than the default tablespace.

`--tablespace=`*`tablespace`*

Create tables in the specified tablespace, rather than the default tablespace.

`--unlogged-tables`

Create all tables as unlogged tables, rather than permanent tables.

Benchmarking Options

pgbench accepts the following command-line benchmarking arguments:

`-c` *`clients`*
`--client=`*`clients`*

Number of clients simulated, that is, number of concurrent database sessions. Default is 1.

`-C`
`--connect`

Establish a new connection for each transaction, rather than doing it just once per client session. This is useful to measure the connection overhead.

`-d`
`--debug`

Print debugging output.

`-D` *`varname=value`*
`--define=`*`varname=value`*

Define a variable for use by a custom script (see below). Multiple `-D` options are allowed.

`-f` *`filename`*
`--file=`*`filename`*

Read transaction script from *`filename`*. See below for details. `-N`, `-S`, and `-f` are mutually exclusive.

`-j` *threads*
`--jobs=`*threads*

Number of worker threads within pgbench. Using more than one thread can be helpful on multi-CPU machines. The number of clients must be a multiple of the number of threads, since each thread is given the same number of client sessions to manage. Default is 1.

`-l`
`--log`

Write the time taken by each transaction to a log file. See below for details.

`-M` *querymode*
`--protocol=`*querymode*

Protocol to use for submitting queries to the server:

- `simple`: use simple query protocol.
- `extended`: use extended query protocol.
- `prepared`: use extended query protocol with prepared statements.

The default is simple query protocol. (See Chapter 49 for more information.)

`-n`
`--no-vacuum`

Perform no vacuuming before running the test. This option is *necessary* if you are running a custom test scenario that does not include the standard tables `pgbench_accounts`, `pgbench_branches`, `pgbench_history`, and `pgbench_tellers`.

`-N`
`--skip-some-updates`

Do not update `pgbench_tellers` and `pgbench_branches`. This will avoid update contention on these tables, but it makes the test case even less like TPC-B.

`-P` *sec*
`--progress=`*sec*

Show progress report every `sec` seconds. The report includes the time since the beginning of the run, the tps since the last report, and the transaction latency average and standard deviation since the last report. Under throttling (`-R`), the latency is computed with respect to the transaction scheduled start time, not the actual transaction beginning time, thus it also includes the average schedule lag time.

`-r`
`--report-latencies`

Report the average per-statement latency (execution time from the perspective of the client) of each command after the benchmark finishes. See below for details.

`-R` *rate*
`--rate=`*rate*

Execute transactions targeting the specified rate instead of running as fast as possible (the default). The rate is given in transactions per second. If the targeted rate is above the maximum possible rate, the rate limit won't impact the results.

The rate is targeted by starting transactions along a Poisson-distributed schedule time line. The expected start time schedule moves forward based on when the client first started, not when the previous transaction ended. That approach means that when transactions go past their original scheduled end time, it is possible for later ones to catch up again.

When throttling is active, the transaction latency reported at the end of the run is calculated from the scheduled start times, so it includes the time each transaction had to wait for the previous transaction to finish. The wait time is called the schedule lag time, and its average and maximum are also reported separately. The transaction latency with respect to the actual transaction start time, i.e. the time spent executing the transaction in the database, can be computed by subtracting the schedule lag time from the reported latency.

A high schedule lag time is an indication that the system cannot process transactions at the specified rate, with the chosen number of clients and threads. When the average transaction execution time is longer than the scheduled interval between each transaction, each successive transaction will fall further behind, and the schedule lag time will keep increasing the longer the test run is. When that happens, you will have to reduce the specified transaction rate.

`-s` *`scale_factor`*
`--scale=`*`scale_factor`*

Report the specified scale factor in pgbench's output. With the built-in tests, this is not necessary; the correct scale factor will be detected by counting the number of rows in the `pgbench_branches` table. However, when testing custom benchmarks (`-f` option), the scale factor will be reported as 1 unless this option is used.

`-S`
`--select-only`

Perform select-only transactions instead of TPC-B-like test.

`-t` *`transactions`*
`--transactions=`*`transactions`*

Number of transactions each client runs. Default is 10.

`-T` *`seconds`*
`--time=`*`seconds`*

Run the test for this many seconds, rather than a fixed number of transactions per client. `-t` and `-T` are mutually exclusive.

`-v`
`--vacuum-all`

Vacuum all four standard tables before running the test. With neither `-n` nor `-v`, pgbench will vacuum the `pgbench_tellers` and `pgbench_branches` tables, and will truncate `pgbench_history`.

`--aggregate-interval=`*`seconds`*

Length of aggregation interval (in seconds). May be used only together with -l - with this option, the log contains per-interval summary (number of transactions, min/max latency and two additional fields useful for variance estimation).

This option is not currently supported on Windows.

`--sampling-rate=`*`rate`*

Sampling rate, used when writing data into the log, to reduce the amount of log generated. If this option is given, only the specified fraction of transactions are logged. 1.0 means all transactions will be logged, 0.05 means only 5% of the transactions will be logged.

Remember to take the sampling rate into account when processing the log file. For example, when computing tps values, you need to multiply the numbers accordingly (e.g. with 0.01 sample rate, you'll only get 1/100 of the actual tps).

Common Options

pgbench accepts the following command-line common arguments:

`-h` *`hostname`*
`--host=`*`hostname`*

The database server's host name

`-p` *`port`*
`--port=`*`port`*

The database server's port number

`-U` *`login`*
`--username=`*`login`*

The user name to connect as

`-V`
`--version`

Print the pgbench version and exit.

`-?`
`--help`

Show help about pgbench command line arguments, and exit.

Notes

What is the "Transaction" Actually Performed in pgbench?

The default transaction script issues seven commands per transaction:

1. `BEGIN;`
2. `UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE aid = :aid;`
3. `SELECT abalance FROM pgbench_accounts WHERE aid = :aid;`
4. `UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE tid = :tid;`
5. `UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE bid = :bid;`
6. `INSERT INTO pgbench_history (tid, bid, aid, delta, mtime) VALUES (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP);`
7. `END;`

If you specify `-N`, steps 4 and 5 aren't included in the transaction. If you specify `-S`, only the `SELECT` is issued.

Custom Scripts

pgbench has support for running custom benchmark scenarios by replacing the default transaction script (described above) with a transaction script read from a file (`-f` option). In this case a "transaction" counts as one execution of a script file. You can even specify multiple scripts (multiple `-f` options), in which case a random one of the scripts is chosen each time a client session starts a new transaction.

The format of a script file is one SQL command per line; multiline SQL commands are not supported. Empty lines and lines beginning with `--` are ignored. Script file lines can also be "meta commands", which are interpreted by pgbench itself, as described below.

There is a simple variable-substitution facility for script files. Variables can be set by the command-line `-D` option, explained above, or by the meta commands explained below. In addition to any variables preset by `-D` command-line options, there are a few variables that are preset automatically, listed in Table G-1. A value specified for these variables using `-D` takes precedence over the automatic presets. Once set, a variable's value can be inserted into a SQL command by writing `:`*`variablename`*. When running more than one client session, each session has its own set of variables.

Table G-1. Automatic variables

Variable	Description
`scale`	current scale factor
`client_id`	unique number identifying the client session (starts from zero)

Script file meta commands begin with a backslash (`\`). Arguments to a meta command are separated by white space. These meta commands are supported:

`\set` *`varname operand1`* `[` *`operator operand2`* `]`

Sets variable *`varname`* to a calculated integer value. Each *`operand`* is either an integer constant or a `:`*`variablename`* reference to a variable having an integer value. The *`operator`* can be `+`, `-`, `*`, or `/`.

Example:

```
\set ntellers 10 * :scale
```

`\setrandom` *`varname min max`*

Sets variable *`varname`* to a random integer value between the limits *`min`* and *`max`* inclusive. Each limit can be either an integer constant or a `:`*`variablename`* reference to a variable having an integer value.

Example:

```
\setrandom aid 1 :naccounts
```

`\sleep` *`number`* `[ us | ms | s ]`

Causes script execution to sleep for the specified duration in microseconds (`us`), milliseconds (`ms`) or seconds (`s`). If the unit is omitted then seconds are the default. *`number`* can be either an integer constant or a `:`*`variablename`* reference to a variable having an integer value.

Example:

```
\sleep 10 ms
```

`\setshell` *varname command* [*argument* ...]

Sets variable *varname* to the result of the shell command *command*. The command must return an integer value through its standard output.

argument can be either a text constant or a `:`*variablename* reference to a variable of any types. If you want to use *argument* starting with colons, you need to add an additional colon at the beginning of *argument*.

Example:

```
\setshell variable_to_be_assigned command literal_argument :variable ::literal_starti
```

`\shell` *command* [*argument* ...]

Same as `\setshell`, but the result is ignored.

Example:

```
\shell command literal_argument :variable ::literal_starting_with_colon
```

As an example, the full definition of the built-in TPC-B-like transaction is:

```
\set nbranches :scale
\set ntellers 10 * :scale
\set naccounts 100000 * :scale
\setrandom aid 1 :naccounts
\setrandom bid 1 :nbranches
\setrandom tid 1 :ntellers
\setrandom delta -5000 5000
BEGIN;
UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE aid = :aid;
SELECT abalance FROM pgbench_accounts WHERE aid = :aid;
UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE tid = :tid;
UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE bid = :bid;
INSERT INTO pgbench_history (tid, bid, aid, delta, mtime) VALUES (:tid, :bid, :aid, :del
END;
```

This script allows each iteration of the transaction to reference different, randomly-chosen rows. (This example also shows why it's important for each client session to have its own variables — otherwise they'd not be independently touching different rows.)

Per-Transaction Logging

With the `-l` option but without the `--aggregate-interval`, pgbench writes the time taken by each transaction to a log file. The log file will be named `pgbench_log.`*nnn*, where *nnn* is the PID of the pgbench process. If the `-j` option is 2 or higher, creating multiple worker threads, each will have its own log file. The first worker will use the same name for its log file as in the standard single worker case. The additional log files for the other workers will be named `pgbench_log.`*nnn*`.`*mmm*, where *mmm* is a sequential number for each worker starting with 1.

The format of the log is:

client_id transaction_no time file_no time_epoch time_us [*schedule_lag*]

where *time* is the total elapsed transaction time in microseconds, *file_no* identifies which script file was used (useful when multiple scripts were specified with `-f`), and *time_epoch*/*time_us* are a UNIX epoch format timestamp and an offset in microseconds (suitable for creating an ISO 8601 timestamp with fractional seconds) showing when the transaction completed. The last field,

schedule_lag, is the difference between the transaction's scheduled start time, and the time it actually started, in microseconds. It is only present when the `--rate` option is used.

Here are example outputs:

```
 0 199 2241 0 1175850568 995598
 0 200 2465 0 1175850568 998079
 0 201 2513 0 1175850569 608
 0 202 2038 0 1175850569 2663
```

When running a long test on hardware that can handle a lot of transactions, the log files can become very large. The `--sampling-rate` option can be used to log only a random sample of transactions.

Aggregated Logging

With the `--aggregate-interval` option, the logs use a bit different format:

```
interval_start num_of_transactions latency_sum latency_2_sum min_latency max_latency [lag_sum lag
```

where *interval_start* is the start of the interval (UNIX epoch format timestamp), *num_of_transactions* is the number of transactions within the interval, *latency_sum* is a sum of latencies (so you can compute average latency easily). The following two fields are useful for variance estimation - *latency_sum* is a sum of latencies and *latency_2_sum* is a sum of 2nd powers of latencies. The last two fields are *min_latency* - a minimum latency within the interval, and *max_latency* - maximum latency within the interval. A transaction is counted into the interval when it was committed. The last four fields, *lag_sum*, *lag_2_sum*, *min_lag*, and *max_lag*, are only present if the --rate option is used. They are calculated from the time each transaction had to wait for the previous one to finish, i.e. the difference between each transaction's scheduled start time and the time it actually started.

Here is example outputs:

```
1345828501 5601 1542744 483552416 61 2573
1345828503 7884 1979812 565806736 60 1479
1345828505 7208 1979422 567277552 59 1391
1345828507 7685 1980268 569784714 60 1398
1345828509 7073 1979779 573489941 236 1411
```

Notice that while the plain (unaggregated) log file contains index of the custom script files, the aggregated log does not. Therefore if you need per script data, you need to aggregate the data on your own.

Per-Statement Latencies

With the `-r` option, pgbench collects the elapsed transaction time of each statement executed by every client. It then reports an average of those values, referred to as the latency for each statement, after the benchmark has finished.

For the default script, the output will look similar to this:

```
starting vacuum...end.
transaction type: TPC-B (sort of)
```

```
scaling factor: 1
query mode: simple
number of clients: 10
number of threads: 1
number of transactions per client: 1000
number of transactions actually processed: 10000/10000
tps = 618.764555 (including connections establishing)
tps = 622.977698 (excluding connections establishing)
statement latencies in milliseconds:
        0.004386        \set nbranches 1 * :scale
        0.001343        \set ntellers 10 * :scale
        0.001212        \set naccounts 100000 * :scale
        0.001310        \setrandom aid 1 :naccounts
        0.001073        \setrandom bid 1 :nbranches
        0.001005        \setrandom tid 1 :ntellers
        0.001078        \setrandom delta -5000 5000
        0.326152        BEGIN;
        0.603376        UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE a
        0.454643        SELECT abalance FROM pgbench_accounts WHERE aid = :aid;
        5.528491        UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE ti
        7.335435        UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE b
        0.371851        INSERT INTO pgbench_history (tid, bid, aid, delta, mtime) VALUES
        1.212976        END;
```

If multiple script files are specified, the averages are reported separately for each script file.

Note that collecting the additional timing information needed for per-statement latency computation adds some overhead. This will slow average execution speed and lower the computed TPS. The amount of slowdown varies significantly depending on platform and hardware. Comparing average TPS values with and without latency reporting enabled is a good way to measure if the timing overhead is significant.

Good Practices

It is very easy to use pgbench to produce completely meaningless numbers. Here are some guidelines to help you get useful results.

In the first place, *never* believe any test that runs for only a few seconds. Use the `-t` or `-T` option to make the run last at least a few minutes, so as to average out noise. In some cases you could need hours to get numbers that are reproducible. It's a good idea to try the test run a few times, to find out if your numbers are reproducible or not.

For the default TPC-B-like test scenario, the initialization scale factor (`-s`) should be at least as large as the largest number of clients you intend to test (`-c`); else you'll mostly be measuring update contention. There are only `-s` rows in the `pgbench_branches` table, and every transaction wants to update one of them, so `-c` values in excess of `-s` will undoubtedly result in lots of transactions blocked waiting for other transactions.

The default test scenario is also quite sensitive to how long it's been since the tables were initialized: accumulation of dead rows and dead space in the tables changes the results. To understand the results you must keep track of the total number of updates and when vacuuming happens. If autovacuum is enabled it can result in unpredictable changes in measured performance.

A limitation of pgbench is that it can itself become the bottleneck when trying to test a large number of client sessions. This can be alleviated by running pgbench on a different machine from the database

server, although low network latency will be essential. It might even be useful to run several pgbench instances concurrently, on several client machines, against the same database server.

vacuumlo

Name

vacuumlo — remove orphaned large objects from a PostgreSQL database

Synopsis

vacuumlo [*option*...] *dbname*...

Description

vacuumlo is a simple utility program that will remove any "orphaned" large objects from a PostgreSQL database. An orphaned large object (LO) is considered to be any LO whose OID does not appear in any oid or lo data column of the database.

If you use this, you may also be interested in the lo_manage trigger in the lo module. lo_manage is useful to try to avoid creating orphaned LOs in the first place.

All databases named on the command line are processed.

Options

vacuumlo accepts the following command-line arguments:

-l *limit*

Remove no more than *limit* large objects per transaction (default 1000). Since the server acquires a lock per LO removed, removing too many LOs in one transaction risks exceeding max_locks_per_transaction. Set the limit to zero if you want all removals done in a single transaction.

-n

Don't remove anything, just show what would be done.

-v

Write a lot of progress messages.

-V
--version

Print the vacuumlo version and exit.

-?
--help

Show help about vacuumlo command line arguments, and exit.

vacuumlo also accepts the following command-line arguments for connection parameters:

`-h` *`hostname`*

Database server's host.

`-p` *`port`*

Database server's port.

`-U` *`username`*

User name to connect as.

`-w`
`--no-password`

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

`-W`

Force vacuumlo to prompt for a password before connecting to a database.

This option is never essential, since vacuumlo will automatically prompt for a password if the server demands password authentication. However, vacuumlo will waste a connection attempt finding out that the server wants a password. In some cases it is worth typing `-W` to avoid the extra connection attempt.

Notes

vacuumlo works by the following method: First, vacuumlo builds a temporary table which contains all of the OIDs of the large objects in the selected database. It then scans through all columns in the database that are of type `oid` or `lo`, and removes matching entries from the temporary table. (Note: Only types with these names are considered; in particular, domains over them are not considered.) The remaining entries in the temporary table identify orphaned LOs. These are removed.

Author

Peter Mount <`peter@retep.org.uk`>

G.2. Server Applications

This section covers PostgreSQL server-related applications in `contrib`. They are typically run on the host where the database server resides. See also Reference III, *PostgreSQL Server Applications* for information about server applications that part of the core PostgreSQL distribution.

pg_archivecleanup

Name

`pg_archivecleanup` — clean up PostgreSQL WAL archive files

Synopsis

`pg_archivecleanup` [*option*...] *archivelocation oldestkeptwalfile*

Description

pg_archivecleanup is designed to be used as an `archive_cleanup_command` to clean up WAL file archives when running as a standby server (see Section 25.2). pg_archivecleanup can also be used as a standalone program to clean WAL file archives.

To configure a standby server to use pg_archivecleanup, put this into its `recovery.conf` configuration file:

```
archive_cleanup_command = 'pg_archivecleanup archivelocation %r'
```

where *archivelocation* is the directory from which WAL segment files should be removed.

When used within archive_cleanup_command, all WAL files logically preceding the value of the `%r` argument will be removed from *archivelocation*. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the *archivelocation* is a transient staging area for this particular standby server, but *not* when the *archivelocation* is intended as a long-term WAL archive area, or when multiple standby servers are recovering from the same archive location.

When used as a standalone program all WAL files logically preceding the *oldestkeptwalfile* will be removed from *archivelocation*. In this mode, if you specify a `.backup` file name, then only the file prefix will be used as the *oldestkeptwalfile*. This allows you to remove all WAL files archived prior to a specific base backup without error. For example, the following example will remove all files older than WAL file name `000000010000003700000010`:

```
pg_archivecleanup -d archive 000000010000003700000010.00000020.backup

pg_archivecleanup:  keep WAL file "archive/000000010000003700000010" and later
pg_archivecleanup:  removing file "archive/00000001000000370000000F"
pg_archivecleanup:  removing file "archive/00000001000000370000000E"
```

pg_archivecleanup assumes that *archivelocation* is a directory readable and writable by the server-owning user.

Options

pg_archivecleanup accepts the following command-line arguments:

`-d`

Print lots of debug logging output on `stderr`.

`-n`

Print the names of the files that would have been removed on `stdout` (performs a dry run).

`-V`
`--version`

Print the pg_archivecleanup version and exit.

`-x` *extension*

When using the program as a standalone utility, provide an extension that will be stripped from all file names before deciding if they should be deleted. This is typically useful for cleaning up archives that have been compressed during storage, and therefore have had an extension added by the compression program. For example: `-x .gz`.

Note that the `.backup` file name passed to the program should not include the extension.

`-?`
`--help`

Show help about pg_archivecleanup command line arguments, and exit.

Notes

pg_archivecleanup is designed to work with PostgreSQL 8.0 and later when used as a standalone utility, or with PostgreSQL 9.0 and later when used as an archive cleanup command.

pg_archivecleanup is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

Examples

On Linux or Unix systems, you might use:

```
archive_cleanup_command = 'pg_archivecleanup -d /mnt/standby/archive %r 2>>cleanup.log'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby. This will:

- produce debugging output in `cleanup.log`
- remove no-longer-needed files from the archive directory

Author

Simon Riggs <simon@2ndquadrant.com>

See Also

pg_standby

pg_standby

Name

pg_standby — supports the creation of a PostgreSQL warm standby server

Synopsis

pg_standby [*option*...] *archivelocation nextwalfile xlogfilepath* [*restartwalfile*]

Description

pg_standby supports creation of a "warm standby" database server. It is designed to be a production-ready program, as well as a customizable template should you require specific modifications.

pg_standby is designed to be a waiting restore_command, which is needed to turn a standard archive recovery into a warm standby operation. Other configuration is required as well, all of which is described in the main server manual (see Section 25.2).

To configure a standby server to use pg_standby, put this into its recovery.conf configuration file:

```
restore_command = 'pg_standby archiveDir %f %p %r'
```

where *archiveDir* is the directory from which WAL segment files should be restored.

If *restartwalfile* is specified, normally by using the %r macro, then all WAL files logically preceding this file will be removed from *archivelocation*. This minimizes the number of files that need to be retained, while preserving crash-restart capability. Use of this parameter is appropriate if the *archivelocation* is a transient staging area for this particular standby server, but *not* when the *archivelocation* is intended as a long-term WAL archive area.

pg_standby assumes that *archivelocation* is a directory readable by the server-owning user. If *restartwalfile* (or -k) is specified, the *archivelocation* directory must be writable too.

There are two ways to fail over to a "warm standby" database server when the master server fails:

Smart Failover

In smart failover, the server is brought up after applying all WAL files available in the archive. This results in zero data loss, even if the standby server has fallen behind, but if there is a lot of unapplied WAL it can be a long time before the standby server becomes ready. To trigger a smart failover, create a trigger file containing the word smart, or just create it and leave it empty.

Fast Failover

In fast failover, the server is brought up immediately. Any WAL files in the archive that have not yet been applied will be ignored, and all transactions in those files are lost. To trigger a fast failover, create a trigger file and write the word fast into it. pg_standby can also be configured to execute a fast failover automatically if no new WAL file appears within a defined interval.

Options

pg_standby accepts the following command-line arguments:

`-c`

Use `cp` or `copy` command to restore WAL files from archive. This is the only supported behavior so this option is useless.

`-d`

Print lots of debug logging output on `stderr`.

`-k`

Remove files from *`archivelocation`* so that no more than this many WAL files before the current one are kept in the archive. Zero (the default) means not to remove any files from *`archivelocation`*. This parameter will be silently ignored if *`restartwalfile`* is specified, since that specification method is more accurate in determining the correct archive cut-off point. Use of this parameter is *deprecated* as of PostgreSQL 8.3; it is safer and more efficient to specify a *`restartwalfile`* parameter. A too small setting could result in removal of files that are still needed for a restart of the standby server, while a too large setting wastes archive space.

`-r` *`maxretries`*

Set the maximum number of times to retry the copy command if it fails (default 3). After each failure, we wait for *`sleeptime`* * *`num_retries`* so that the wait time increases progressively. So by default, we will wait 5 secs, 10 secs, then 15 secs before reporting the failure back to the standby server. This will be interpreted as end of recovery and the standby will come up fully as a result.

`-s` *`sleeptime`*

Set the number of seconds (up to 60, default 5) to sleep between tests to see if the WAL file to be restored is available in the archive yet. The default setting is not necessarily recommended; consult Section 25.2 for discussion.

`-t` *`triggerfile`*

Specify a trigger file whose presence should cause failover. It is recommended that you use a structured file name to avoid confusion as to which server is being triggered when multiple servers exist on the same system; for example `/tmp/pgsql.trigger.5432`.

`-V`
`--version`

Print the pg_standby version and exit.

`-w` *`maxwaittime`*

Set the maximum number of seconds to wait for the next WAL file, after which a fast failover will be performed. A setting of zero (the default) means wait forever. The default setting is not necessarily recommended; consult Section 25.2 for discussion.

`-?`
`--help`

Show help about pg_standby command line arguments, and exit.

Notes

pg_standby is designed to work with PostgreSQL 8.2 and later.

PostgreSQL 8.3 provides the `%r` macro, which is designed to let pg_standby know the last file it needs to keep. With PostgreSQL 8.2, the `-k` option must be used if archive cleanup is required. This option remains available in 8.3, but its use is deprecated.

PostgreSQL 8.4 provides the `recovery_end_command` option. Without this option a leftover trigger file can be hazardous.

pg_standby is written in C and has an easy-to-modify source code, with specifically designated sections to modify for your own needs

Examples

On Linux or Unix systems, you might use:

```
archive_command = 'cp %p .../archive/%f'

restore_command = 'pg_standby -d -s 2 -t /tmp/pgsql.trigger.5442 .../archive %f %p %r 2>

recovery_end_command = 'rm -f /tmp/pgsql.trigger.5442'
```

where the archive directory is physically located on the standby server, so that the `archive_command` is accessing it across NFS, but the files are local to the standby (enabling use of `ln`). This will:

- produce debugging output in `standby.log`
- sleep for 2 seconds between checks for next WAL file availability
- stop waiting only when a trigger file called `/tmp/pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

On Windows, you might use:

```
archive_command = 'copy %p ...\\archive\\%f'

restore_command = 'pg_standby -d -s 5 -t C:\pgsql.trigger.5442 ...\archive %f %p %r 2>>s

recovery_end_command = 'del C:\pgsql.trigger.5442'
```

Note that backslashes need to be doubled in the `archive_command`, but *not* in the `restore_command` or `recovery_end_command`. This will:

- use the `copy` command to restore WAL files from archive
- produce debugging output in `standby.log`
- sleep for 5 seconds between checks for next WAL file availability

- stop waiting only when a trigger file called `C:\pgsql.trigger.5442` appears, and perform failover according to its content
- remove the trigger file when recovery ends
- remove no-longer-needed files from the archive directory

The `copy` command on Windows sets the final file size before the file is completely copied, which would ordinarily confuse pg_standby. Therefore pg_standby waits `sleeptime` seconds once it sees the proper file size. GNUWin32's `cp` sets the file size only after the file copy is complete.

Since the Windows example uses `copy` at both ends, either or both servers might be accessing the archive directory across the network.

Author

Simon Riggs <`simon@2ndquadrant.com`>

See Also

pg_archivecleanup

pg_test_fsync

Name

pg_test_fsync — determine fastest wal_sync_method for PostgreSQL

Synopsis

pg_test_fsync [*option*...]

Description

pg_test_fsync is intended to give you a reasonable idea of what the fastest wal_sync_method is on your specific system, as well as supplying diagnostic information in the event of an identified I/O problem. However, differences shown by pg_test_fsync might not make any significant difference in real database throughput, especially since many database servers are not speed-limited by their transaction logs. pg_test_fsync reports average file sync operation time in microseconds for each wal_sync_method, which can also be used to inform efforts to optimize the value of commit_delay.

Options

pg_test_fsync accepts the following command-line options:

-f
--filename

Specifies the file name to write test data in. This file should be in the same file system that the pg_xlog directory is or will be placed in. (pg_xlog contains the WAL files.) The default is pg_test_fsync.out in the current directory.

-s
--secs-per-test

Specifies the number of seconds for each test. The more time per test, the greater the test's accuracy, but the longer it takes to run. The default is 5 seconds, which allows the program to complete in under 2 minutes.

-V
--version

Print the pg_test_fsync version and exit.

-?
--help

Show help about pg_test_fsync command line arguments, and exit.

Author

Bruce Momjian <bruce@momjian.us>

See Also

postgres

pg_test_timing

Name

`pg_test_timing` — measure timing overhead

Synopsis

`pg_test_timing` [*option*...]

Description

pg_test_timing is a tool to measure the timing overhead on your system and confirm that the system time never moves backwards. Systems that are slow to collect timing data can give less accurate `EXPLAIN ANALYZE` results.

Options

pg_test_timing accepts the following command-line options:

`-d` *duration*
`--duration=`*duration*

Specifies the test duration, in seconds. Longer durations give slightly better accuracy, and are more likely to discover problems with the system clock moving backwards. The default test duration is 3 seconds.

`-V`
`--version`

Print the pg_test_timing version and exit.

`-?`
`--help`

Show help about pg_test_timing command line arguments, and exit.

Usage

Interpreting results

Good results will show most (>90%) individual timing calls take less than one microsecond. Average per loop overhead will be even lower, below 100 nanoseconds. This example from an Intel i7-860 system using a TSC clock source shows excellent performance:

```
Testing timing overhead for 3 seconds.
Per loop time including overhead: 35.96 nsec
Histogram of timing durations:
```

```
< usec   % of total      count
     1     96.40465   80435604
     2      3.59518    2999652
     4      0.00015        126
     8      0.00002         13
    16      0.00000          2
```

Note that different units are used for the per loop time than the histogram. The loop can have resolution within a few nanoseconds (nsec), while the individual timing calls can only resolve down to one microsecond (usec).

Measuring executor timing overhead

When the query executor is running a statement using `EXPLAIN ANALYZE`, individual operations are timed as well as showing a summary. The overhead of your system can be checked by counting rows with the psql program:

```
CREATE TABLE t AS SELECT * FROM generate_series(1,100000);
\timing
SELECT COUNT(*) FROM t;
EXPLAIN ANALYZE SELECT COUNT(*) FROM t;
```

The i7-860 system measured runs the count query in 9.8 ms while the `EXPLAIN ANALYZE` version takes 16.6 ms, each processing just over 100,000 rows. That 6.8 ms difference means the timing overhead per row is 68 ns, about twice what pg_test_timing estimated it would be. Even that relatively small amount of overhead is making the fully timed count statement take almost 70% longer. On more substantial queries, the timing overhead would be less problematic.

Changing time sources

On some newer Linux systems, it's possible to change the clock source used to collect timing data at any time. A second example shows the slowdown possible from switching to the slower acpi_pm time source, on the same system used for the fast results above:

```
# cat /sys/devices/system/clocksource/clocksource0/available_clocksource
tsc hpet acpi_pm
# echo acpi_pm > /sys/devices/system/clocksource/clocksource0/current_clocksource
# pg_test_timing
Per loop time including overhead: 722.92 nsec
Histogram of timing durations:
< usec   % of total      count
     1     27.84870    1155682
     2     72.05956    2990371
     4      0.07810       3241
     8      0.01357        563
    16      0.00007          3
```

In this configuration, the sample `EXPLAIN ANALYZE` above takes 115.9 ms. That's 1061 nsec of timing overhead, again a small multiple of what's measured directly by this utility. That much timing

overhead means the actual query itself is only taking a tiny fraction of the accounted for time, most of it is being consumed in overhead instead. In this configuration, any `EXPLAIN ANALYZE` totals involving many timed operations would be inflated significantly by timing overhead.

FreeBSD also allows changing the time source on the fly, and it logs information about the timer selected during boot:

```
# dmesg | grep "Timecounter"
Timecounter "ACPI-fast" frequency 3579545 Hz quality 900
Timecounter "i8254" frequency 1193182 Hz quality 0
Timecounters tick every 10.000 msec
Timecounter "TSC" frequency 2531787134 Hz quality 800
# sysctl kern.timecounter.hardware=TSC
kern.timecounter.hardware: ACPI-fast -> TSC
```

Other systems may only allow setting the time source on boot. On older Linux systems the "clock" kernel setting is the only way to make this sort of change. And even on some more recent ones, the only option you'll see for a clock source is "jiffies". Jiffies are the older Linux software clock implementation, which can have good resolution when it's backed by fast enough timing hardware, as in this example:

```
$ cat /sys/devices/system/clocksource/clocksource0/available_clocksource
jiffies
$ dmesg | grep time.c
time.c: Using 3.579545 MHz WALL PM GTOD PIT/TSC timer.
time.c: Detected 2400.153 MHz processor.
$ pg_test_timing
Testing timing overhead for 3 seconds.
Per timing duration including loop overhead: 97.75 ns
Histogram of timing durations:
< usec   % of total      count
     1     90.23734   27694571
     2      9.75277    2993204
     4      0.00981       3010
     8      0.00007         22
    16      0.00000          1
    32      0.00000          1
```

Clock hardware and timing accuracy

Collecting accurate timing information is normally done on computers using hardware clocks with various levels of accuracy. With some hardware the operating systems can pass the system clock time almost directly to programs. A system clock can also be derived from a chip that simply provides timing interrupts, periodic ticks at some known time interval. In either case, operating system kernels provide a clock source that hides these details. But the accuracy of that clock source and how quickly it can return results varies based on the underlying hardware.

Inaccurate time keeping can result in system instability. Test any change to the clock source very carefully. Operating system defaults are sometimes made to favor reliability over best accuracy. And if you are using a virtual machine, look into the recommended time sources compatible with it. Virtual hardware faces additional difficulties when emulating timers, and there are often per operating system settings suggested by vendors.

The Time Stamp Counter (TSC) clock source is the most accurate one available on current generation CPUs. It's the preferred way to track the system time when it's supported by the operating system and the TSC clock is reliable. There are several ways that TSC can fail to provide an accurate timing source, making it unreliable. Older systems can have a TSC clock that varies based on the CPU temperature, making it unusable for timing. Trying to use TSC on some older multicore CPUs can give a reported time that's inconsistent among multiple cores. This can result in the time going backwards, a problem this program checks for. And even the newest systems can fail to provide accurate TSC timing with very aggressive power saving configurations.

Newer operating systems may check for the known TSC problems and switch to a slower, more stable clock source when they are seen. If your system supports TSC time but doesn't default to that, it may be disabled for a good reason. And some operating systems may not detect all the possible problems correctly, or will allow using TSC even in situations where it's known to be inaccurate.

The High Precision Event Timer (HPET) is the preferred timer on systems where it's available and TSC is not accurate. The timer chip itself is programmable to allow up to 100 nanosecond resolution, but you may not see that much accuracy in your system clock.

Advanced Configuration and Power Interface (ACPI) provides a Power Management (PM) Timer, which Linux refers to as the acpi_pm. The clock derived from acpi_pm will at best provide 300 nanosecond resolution.

Timers used on older PC hardware include the 8254 Programmable Interval Timer (PIT), the real-time clock (RTC), the Advanced Programmable Interrupt Controller (APIC) timer, and the Cyclone timer. These timers aim for millisecond resolution.

Author

Ants Aasma <ants.aasma@eesti.ee>

See Also

EXPLAIN

pg_upgrade

Name

pg_upgrade — upgrade a PostgreSQL server instance

Synopsis

```
pg_upgrade -b oldbindir -B newbindir -d olddatadir -D newdatadir [option...]
```

Description

pg_upgrade (formerly called pg_migrator) allows data stored in PostgreSQL data files to be upgraded to a later PostgreSQL major version without the data dump/reload typically required for major version upgrades, e.g. from 8.4.7 to the current major release of PostgreSQL. It is not required for minor version upgrades, e.g. from 9.0.1 to 9.0.4.

Major PostgreSQL releases regularly add new features that often change the layout of the system tables, but the internal data storage format rarely changes. pg_upgrade uses this fact to perform rapid upgrades by creating new system tables and simply reusing the old user data files. If a future major release ever changes the data storage format in a way that makes the old data format unreadable, pg_upgrade will not be usable for such upgrades. (The community will attempt to avoid such situations.)

pg_upgrade does its best to make sure the old and new clusters are binary-compatible, e.g. by checking for compatible compile-time settings, including 32/64-bit binaries. It is important that any external modules are also binary compatible, though this cannot be checked by pg_upgrade.

pg_upgrade supports upgrades from 8.3.X and later to the current major release of PostgreSQL, including snapshot and alpha releases.

Options

pg_upgrade accepts the following command-line arguments:

`-b` *bindir*
`--old-bindir=`*bindir*

the old PostgreSQL executable directory; environment variable `PGBINOLD`

`-B` *bindir*
`--new-bindir=`*bindir*

the new PostgreSQL executable directory; environment variable `PGBINNEW`

`-c`
`--check`

check clusters only, don't change any data

`-d` *datadir*
`--old-datadir=`*datadir*

the old cluster data directory; environment variable `PGDATAOLD`

`-D` *datadir*
`--new-datadir=`*datadir*

the new cluster data directory; environment variable `PGDATANEW`

`-j`
`--jobs`

number of simultaneous processes or threads to use

`-k`
`--link`

use hard links instead of copying files to the new cluster (use junction points on Windows)

`-o` *options*
`--old-options` *options*

options to be passed directly to the old `postgres` command

`-O` *options*
`--new-options` *options*

options to be passed directly to the new `postgres` command

`-p` *port*
`--old-port=`*port*

the old cluster port number; environment variable `PGPORTOLD`

`-P` *port*
`--new-port=`*port*

the new cluster port number; environment variable `PGPORTNEW`

`-r`
`--retain`

retain SQL and log files even after successful completion

`-U` *username*
`--username=`*username*

cluster's super user name; environment variable `PGUSER`

`-v`
`--verbose`

enable verbose internal logging

`-V`
`--version`

display version information, then exit

`-?`
`--help`

show help, then exit

Usage

These are the steps to perform an upgrade with pg_upgrade:

1. Optionally move the old cluster

   If you are using a version-specific installation directory, e.g. `/opt/PostgreSQL/9.1`, you do not need to move the old cluster. The graphical installers all use version-specific installation directories.

   If your installation directory is not version-specific, e.g. `/usr/local/pgsql`, it is necessary to move the current PostgreSQL install directory so it does not interfere with the new PostgreSQL installation. Once the current PostgreSQL server is shut down, it is safe to rename the PostgreSQL installation directory; assuming the old directory is `/usr/local/pgsql`, you can do:

   ```
   mv /usr/local/pgsql /usr/local/pgsql.old
   ```
   to rename the directory.

2. For source installs, build the new version

   Build the new PostgreSQL source with `configure` flags that are compatible with the old cluster. pg_upgrade will check `pg_controldata` to make sure all settings are compatible before starting the upgrade.

3. Install the new PostgreSQL binaries

   Install the new server's binaries and support files.

   For source installs, if you wish to install the new server in a custom location, use the `prefix` variable:

   ```
   make prefix=/usr/local/pgsql.new install
   ```

4. Install pg_upgrade and pg_upgrade_support

   Install the pg_upgrade binary and pg_upgrade_support library in the new PostgreSQL installation.

5. Initialize the new PostgreSQL cluster

   Initialize the new cluster using `initdb`. Again, use compatible `initdb` flags that match the old cluster. Many prebuilt installers do this step automatically. There is no need to start the new cluster.

6. Install custom shared object files

   Install any custom shared object files (or DLLs) used by the old cluster into the new cluster, e.g. `pgcrypto.so`, whether they are from `contrib` or some other source. Do not install the schema definitions, e.g. `pgcrypto.sql`, because these will be upgraded from the old cluster.

7. Adjust authentication

   `pg_upgrade` will connect to the old and new servers several times, so you might want to set authentication to `peer` in `pg_hba.conf` or use a `~/.pgpass` file (see Section 31.15).

8. Stop both servers

   Make sure both database servers are stopped using, on Unix, e.g.:

   ```
   pg_ctl -D /opt/PostgreSQL/8.4 stop
   pg_ctl -D /opt/PostgreSQL/9.0 stop
   ```
   or on Windows, using the proper service names:

   ```
   NET STOP postgresql-8.4
   NET STOP postgresql-9.0
   ```

or

```
NET STOP pgsql-8.3  (PostgreSQL 8.3 and older used a different service name)
```

9. Run pg_upgrade

   Always run the pg_upgrade binary of the new server, not the old one. pg_upgrade requires the specification of the old and new cluster's data and executable (`bin`) directories. You can also specify user and port values, and whether you want the data linked instead of copied (the default).

   If you use link mode, the upgrade will be much faster (no file copying) and use less disk space, but you will not be able to access your old cluster once you start the new cluster after the upgrade. Link mode also requires that the old and new cluster data directories be in the same file system. (Tablespaces and `pg_xlog` can be on different file systems.) See `pg_upgrade --help` for a full list of options.

   The `--jobs` option allows multiple CPU cores to be used for copying/linking of files and to dump and reload database schemas in parallel; a good place to start is the maximum of the number of CPU cores and tablespaces. This option can dramatically reduce the time to upgrade a multi-database server running on a multiprocessor machine.

   For Windows users, you must be logged into an administrative account, and then start a shell as the `postgres` user and set the proper path:

   ```
   RUNAS /USER:postgres "CMD.EXE"
   SET PATH=%PATH%;C:\Program Files\PostgreSQL\9.0\bin;
   ```
   and then run pg_upgrade with quoted directories, e.g.:

   ```
   pg_upgrade.exe
           --old-datadir "C:/Program Files/PostgreSQL/8.4/data"
           --new-datadir "C:/Program Files/PostgreSQL/9.0/data"
           --old-bindir "C:/Program Files/PostgreSQL/8.4/bin"
           --new-bindir "C:/Program Files/PostgreSQL/9.0/bin"
   ```
   Once started, `pg_upgrade` will verify the two clusters are compatible and then do the upgrade. You can use `pg_upgrade --check` to perform only the checks, even if the old server is still running. `pg_upgrade --check` will also outline any manual adjustments you will need to make after the upgrade. If you are going to be using link mode, you should use the `--link` option with `--check` to enable link-mode-specific checks. `pg_upgrade` requires write permission in the current directory.

   Obviously, no one should be accessing the clusters during the upgrade. pg_upgrade defaults to running servers on port 50432 to avoid unintended client connections. You can use the same port number for both clusters when doing an upgrade because the old and new clusters will not be running at the same time. However, when checking an old running server, the old and new port numbers must be different.

   If an error occurs while restoring the database schema, `pg_upgrade` will exit and you will have to revert to the old cluster as outlined in step 14 below. To try `pg_upgrade` again, you will need to modify the old cluster so the pg_upgrade schema restore succeeds. If the problem is a contrib module, you might need to uninstall the contrib module from the old cluster and install it in the new cluster after the upgrade, assuming the module is not being used to store user data.

10. Restore `pg_hba.conf`

    If you modified `pg_hba.conf`, restore its original settings. It might also be necessary to adjust other configuration files in the new cluster to match the old cluster, e.g. `postgresql.conf`.

11. Post-Upgrade processing

If any post-upgrade processing is required, pg_upgrade will issue warnings as it completes. It will also generate script files that must be run by the administrator. The script files will connect to each database that needs post-upgrade processing. Each script should be run using:

```
psql --username postgres --file script.sql postgres
```

The scripts can be run in any order and can be deleted once they have been run.

> **Caution**
>
> In general it is unsafe to access tables referenced in rebuild scripts until the rebuild scripts have run to completion; doing so could yield incorrect results or poor performance. Tables not referenced in rebuild scripts can be accessed immediately.

12. Statistics

    Because optimizer statistics are not transferred by `pg_upgrade`, you will be instructed to run a command to regenerate that information at the end of the upgrade. You might need to set connection parameters to match your new cluster.

13. Delete old cluster

    Once you are satisfied with the upgrade, you can delete the old cluster's data directories by running the script mentioned when `pg_upgrade` completes. (Automatic deletion is not possible if you have user-defined tablespaces inside the old data directory.) You can also delete the old installation directories (e.g. `bin`, `share`).

14. Reverting to old cluster

    If, after running `pg_upgrade`, you wish to revert to the old cluster, there are several options:

    - If you ran `pg_upgrade` with `--check`, no modifications were made to the old cluster and you can re-use it anytime.
    - If you ran `pg_upgrade` with `--link`, the data files are shared between the old and new cluster. If you started the new cluster, the new server has written to those shared files and it is unsafe to use the old cluster.
    - If you ran `pg_upgrade` *without* `--link` or did not start the new server, the old cluster was not modified except that, if linking started, a `.old` suffix was appended to `$PGDATA/global/pg_control`. To reuse the old cluster, possibly remove the `.old` suffix from `$PGDATA/global/pg_control`; you can then restart the old cluster.

Notes

pg_upgrade does not support upgrading of databases containing these `reg*` OID-referencing system data types: `regproc`, `regprocedure`, `regoper`, `regoperator`, `regconfig`, and `regdictionary`. (`regtype` can be upgraded.)

All failure, rebuild, and reindex cases will be reported by pg_upgrade if they affect your installation; post-upgrade scripts to rebuild tables and indexes will be generated automatically. If you are trying to automate the upgrade of many clusters, you should find that clusters with identical database schemas require the same post-upgrade steps for all cluster upgrades; this is because the post-upgrade steps are based on the database schemas, and not user data.

For deployment testing, create a schema-only copy of the old cluster, insert dummy data, and upgrade that.

If you are upgrading a pre-PostgreSQL 9.2 cluster that uses a configuration-file-only directory, you must pass the real data directory location to pg_upgrade, and pass the configuration directory location to the server, e.g. `-d /real-data-directory -o '-D /configuration-directory'`.

If using a pre-9.1 old server that is using a non-default Unix-domain socket directory or a default that differs from the default of the new cluster, set `PGHOST` to point to the old server's socket location. (This is not relevant on Windows.)

A Log-Shipping Standby Server (Section 25.2) cannot be upgraded because the server must allow writes. The simplest way is to upgrade the primary and use `rsync` to rebuild the standbys. You can run `rsync` while the primary is down, or as part of a base backup (Section 24.3.2) which overwrites the old standby cluster.

If you want to use link mode and you do not want your old cluster to be modified when the new cluster is started, make a copy of the old cluster and upgrade that in link mode. To make a valid copy of the old cluster, use `rsync` to create a dirty copy of the old cluster while the server is running, then shut down the old server and run `rsync` again to update the copy with any changes to make it consistent. You might want to exclude some files, e.g. `postmaster.pid`, as documented in Section 24.3.3. If your file system supports file system snapshots or copy-on-write file copies, you can use that to make a backup of the old cluster and tablespaces, though the snapshot and copies must be created simultaneously or while the database server is down.

Limitations in Upgrading from PostgreSQL 8.3

Upgrading *from* PostgreSQL 8.3 has additional restrictions not present when upgrading from later PostgreSQL releases. For example, pg_upgrade will not work for upgrading from 8.3 if a user column is defined as:

- a `tsquery` data type
- data type `name` and is not the first column

You must drop any such columns and upgrade them manually.

pg_upgrade will not work if the `ltree` contrib module is installed in a database.

pg_upgrade will require a table rebuild if:

- a user column is of data type `tsvector`

pg_upgrade will require a reindex if:

- an index is of type hash or GIN
- an index uses `bpchar_pattern_ops`

Also, the default datetime storage format changed to integer after PostgreSQL 8.3. pg_upgrade will check that the datetime storage format used by the old and new clusters match. Make sure your new cluster is built with the configure flag `--disable-integer-datetimes`.

For Windows users, note that due to different integer datetimes settings used by the graphical installer and the MSI installer, it is only possible to upgrade from version 8.3 of the installer distribution to version 8.4 or later of the installer distribution. It is not possible to upgrade from the MSI installer to the new graphical installer.

See Also

initdb, pg_ctl, pg_dump, postgres

pg_xlogdump

Name

`pg_xlogdump` — Display a human-readable rendering of the write-ahead log of a PostgreSQL database cluster

Synopsis

`pg_xlogdump` [`option`...] [`startseg` [`endseg`]]

Description

`pg_xlogdump` displays the write-ahead log (WAL) and is mainly useful for debugging or educational purposes.

This utility can only be run by the user who installed the server, because it requires read-only access to the data directory.

Options

The following command-line options control the location and format of the output:

`startseg`

Start reading at the specified log segment file. This implicitly determines the path in which files will be searched for, and the timeline to use.

`endseg`

Stop after reading the specified log segment file.

`-b`
`--bkp-details`

Output detailed information about backup blocks.

`-e` *`end`*
`--end=`*`end`*

Stop reading at the specified log position, instead of reading to the end of the log stream.

`-f`
`--follow`

After reaching the end of valid WAL, keep polling once per second for new WAL to appear.

`-n` *`limit`*
`--limit=`*`limit`*

Display the specified number of records, then stop.

`-p` *path*
`--path=`*path*

Directory in which to find log segment files. The default is to search for them in the `pg_xlog` subdirectory of the current directory.

`-r` *rmgr*
`--rmgr=`*rmgr*

Only display records generated by the specified resource manager. If `list` is passed as name, print a list of valid resource manager names, and exit.

`-s` *start*
`--start=`*start*

Log position at which to start reading. The default is to start reading the first valid log record found in the earliest file found.

`-t` *timeline*
`--timelime=`*timeline*

Timeline from which to read log records. The default is to use the value in `startseg`, if that is specified; otherwise, the default is 1.

`-V`
`--version`

Print the pg_xlogdump version and exit.

`-x` *xid*
`--xid=`*xid*

Only display records marked with the given TransactionId.

`-?`
`--help`

Show help about pg_xlogdump command line arguments, and exit.

Notes

Can give wrong results when the server is running.

Only the specified timeline is displayed (or the default, if none is specified). Records in other timelines are ignored.

See Also

Section 29.5

Appendix H. External Projects

PostgreSQL is a complex software project, and managing the project is difficult. We have found that many enhancements to PostgreSQL can be more efficiently developed separately from the core project.

H.1. Client Interfaces

There are only two client interfaces included in the base PostgreSQL distribution:

- libpq is included because it is the primary C language interface, and because many other client interfaces are built on top of it.
- ECPG is included because it depends on the server-side SQL grammar, and is therefore sensitive to changes in PostgreSQL itself.

All other language interfaces are external projects and are distributed separately. Table H-1 includes a list of some of these projects. Note that some of these packages might not be released under the same license as PostgreSQL. For more information on each language interface, including licensing terms, refer to its website and documentation.

Table H-1. Externally Maintained Client Interfaces

Name	Language	Comments	Website
DBD::Pg	Perl	Perl DBI driver	http://search.cpan.org/dist/DBD-Pg/
JDBC	JDBC	Type 4 JDBC driver	http://jdbc.postgresql.org/
libpqxx	C++	New-style C++ interface	http://pqxx.org/
Npgsql	.NET	.NET data provider	http://npgsql.projects.postgresql.org/
pgtclng	Tcl		http://sourceforge.net/projects/pgtclng/
psqlODBC	ODBC	ODBC driver	http://psqlodbc.projects.postgresql.org/
psycopg	Python	DB API 2.0-compliant	http://initd.org/psycopg/

H.2. Administration Tools

There are several administration tools available for PostgreSQL. The most popular is pgAdmin III[1], and there are several commercially available ones as well.

1. http://www.pgadmin.org/

H.3. Procedural Languages

PostgreSQL includes several procedural languages with the base distribution: PL/pgSQL, PL/Tcl, PL/Perl, and PL/Python.

In addition, there are a number of procedural languages that are developed and maintained outside the core PostgreSQL distribution. Table H-2 lists some of these packages. Note that some of these projects might not be released under the same license as PostgreSQL. For more information on each procedural language, including licensing information, refer to its website and documentation.

Table H-2. Externally Maintained Procedural Languages

Name	Language	Website
PL/Java	Java	http://pljava.projects.postgresql.org/
PL/PHP	PHP	http://www.commandprompt.com/community/plph
PL/Py	Python	http://python.projects.postgresql.org/backend/
PL/R	R	http://www.joeconway.com/plr/
PL/Ruby	Ruby	http://raa.ruby-lang.org/project/pl-ruby/
PL/Scheme	Scheme	http://plscheme.projects.postgresql.org/
PL/sh	Unix shell	http://plsh.projects.postgresql.org/

H.4. Extensions

PostgreSQL is designed to be easily extensible. For this reason, extensions loaded into the database can function just like features that are built in. The `contrib/` directory shipped with the source code contains several extensions, which are described in Appendix F. Other extensions are developed independently, like PostGIS[2]. Even PostgreSQL replication solutions can be developed externally. For example, Slony-I[3] is a popular master/standby replication solution that is developed independently from the core project.

2. http://www.postgis.org/
3. http://www.slony.info

Appendix I. The Source Code Repository

The PostgreSQL source code is stored and managed using the Git version control system. A public mirror of the master repository is available; it is updated within a minute of any change to the master repository.

Our wiki, http://wiki.postgresql.org/wiki/Working_with_Git, has some discussion on working with Git.

Note that building PostgreSQL from the source repository requires reasonably up-to-date versions of bison, flex, and Perl. These tools are not needed to build from a distribution tarball since the files they are used to build are included in the tarball. Other tool requirements are the same as shown in Chapter 15.

I.1. Getting The Source via Git

With Git you will make a copy of the entire code repository on your local machine, so you will have access to all history and branches offline. This is the fastest and most flexible way to develop or test patches.

Git

1. You will need an installed version of Git, which you can get from http://git-scm.com. Many systems already have a recent version of Git installed by default, or available in their package distribution system.
2. To begin using the Git repository, make a clone of the official mirror:

   ```
   git clone git://git.postgresql.org/git/postgresql.git
   ```

   This will copy the full repository to your local machine, so it may take a while to complete, especially if you have a slow Internet connection. The files will be placed in a new subdirectory `postgresql` of your current directory.

   The Git mirror can also be reached via the HTTP protocol, if for example a firewall is blocking access to the Git protocol. Just change the URL prefix to `http`, as in:

   ```
   git clone http://git.postgresql.org/git/postgresql.git
   ```

   The HTTP protocol is less efficient than the Git protocol, so it will be slower to use.
3. Whenever you want to get the latest updates in the system, `cd` into the repository, and run:

   ```
   git fetch
   ```

Git can do a lot more things than just fetch the source. For more information, consult the Git man pages, or see the website at http://git-scm.com.

Appendix J. Documentation

PostgreSQL has four primary documentation formats:

- Plain text, for pre-installation information
- HTML, for on-line browsing and reference
- PDF or PostScript, for printing
- man pages, for quick reference.

Additionally, a number of plain-text `README` files can be found throughout the PostgreSQL source tree, documenting various implementation issues.

HTML documentation and man pages are part of a standard distribution and are installed by default. PDF and PostScript format documentation is available separately for download.

J.1. DocBook

The documentation sources are written in *DocBook*, which is a markup language superficially similar to HTML. Both of these languages are applications of the *Standard Generalized Markup Language*, SGML, which is essentially a language for describing other languages. In what follows, the terms DocBook and SGML are both used, but technically they are not interchangeable.

DocBook allows an author to specify the structure and content of a technical document without worrying about presentation details. A document style defines how that content is rendered into one of several final forms. DocBook is maintained by the OASIS group[1]. The official DocBook site[2] has good introductory and reference documentation and a complete O'Reilly book for your online reading pleasure. The NewbieDoc Docbook Guide[3] is very helpful for beginners. The FreeBSD Documentation Project[4] also uses DocBook and has some good information, including a number of style guidelines that might be worth considering.

J.2. Tool Sets

The following tools are used to process the documentation. Some might be optional, as noted.

DocBook DTD[5]

> This is the definition of DocBook itself. We currently use version 4.2; you cannot use later or earlier versions. You need the SGML variant of the DocBook DTD, but to build man pages you also need the XML variant of the same version.

1. http://www.oasis-open.org
2. http://www.oasis-open.org/docbook/
3. http://newbiedoc.sourceforge.net/metadoc/docbook-guide.html
4. http://www.freebsd.org/docproj/docproj.html
5. http://www.oasis-open.org/docbook/

ISO 8879 character entities[6]

These are required by DocBook but are distributed separately because they are maintained by ISO.

DocBook DSSSL Stylesheets[7]

These contain the processing instructions for converting the DocBook sources to other formats, such as HTML.

DocBook XSL Stylesheets[8]

This is another stylesheet for converting DocBook to other formats. We currently use this to produce man pages and optionally HTMLHelp. You can also use this toolchain to produce HTML or PDF output, but official PostgreSQL releases use the DSSSL stylesheets for that.

The minimum required version is currently 1.74.0.

OpenJade[9]

This is the base package of SGML processing. It contains an SGML parser, a DSSSL processor (that is, a program to convert SGML to other formats using DSSSL stylesheets), as well as a number of related tools. Jade is now being maintained by the OpenJade group, no longer by James Clark.

Libxslt[10] for `xsltproc`

This is the processing tool to use with the XSLT stylesheets (like `jade` is the processing tool for DSSSL stylesheets).

JadeTeX[11]

If you want to, you can also install JadeTeX to use TeX as a formatting backend for Jade. JadeTeX can create PostScript or PDF files (the latter with bookmarks).

However, the output from JadeTeX is inferior to what you get from the RTF backend. Particular problem areas are tables and various artifacts of vertical and horizontal spacing. Also, there is no opportunity to manually polish the results.

We have documented experience with several installation methods for the various tools that are needed to process the documentation. These will be described below. There might be some other packaged distributions for these tools. Please report package status to the documentation mailing list, and we will include that information here.

J.2.1. Linux RPM Installation

Most vendors provide a complete RPM set for DocBook processing in their distribution. Look for an "SGML" option while installing, or the following packages: `sgml-common`, `docbook`, `stylesheets`, `openjade` (or `jade`). You may also need `sgml-tools` and either `xsltproc` or `libxslt`. If your distributor does not provide these then you should be able to make use of the packages from some other, reasonably compatible vendor.

6. http://www.oasis-open.org/cover/ISOEnts.zip
7. http://wiki.docbook.org/DocBookDssslStylesheetDocs
8. http://wiki.docbook.org/DocBookXslStylesheets
9. http://openjade.sourceforge.net
10. http://xmlsoft.org/XSLT/
11. http://jadetex.sourceforge.net

J.2.2. FreeBSD Installation

The FreeBSD Documentation Project is itself a heavy user of DocBook, so it comes as no surprise that there is a full set of "ports" of the documentation tools available on FreeBSD. The following ports need to be installed to build the documentation on FreeBSD.

- `textproc/sp`
- `textproc/openjade`
- `textproc/iso8879`
- `textproc/dsssl-docbook-modular`
- `textproc/docbook-420`

A number of things from `/usr/ports/print` (`tex`, `jadetex`) might also be of interest.

It's possible that the ports do not update the main catalog file in `/usr/local/share/sgml/catalog.ports` or that the order isn't proper. Be sure to have the following lines in the beginning of the file:

```
CATALOG "openjade/catalog"
CATALOG "iso8879/catalog"
CATALOG "docbook/dsssl/modular/catalog"
CATALOG "docbook/4.2/catalog"
```

If you do not want to edit the file you can also set the environment variable `SGML_CATALOG_FILES` to a colon-separated list of catalog files (such as the one above).

More information about the FreeBSD documentation tools can be found in the FreeBSD Documentation Project's instructions[12].

J.2.3. Debian Packages

There is a full set of packages of the documentation tools available for Debian GNU/Linux. To install, simply use:

```
apt-get install docbook docbook-dsssl docbook-xsl openjade1.3 opensp xsltproc
```

J.2.4. OS X

If you use MacPorts, the following will get you set up:

```
sudo port install docbook-dsssl docbook-sgml-4.2 docbook-xml-4.2 docbook-xsl libxslt ope
```

12. http://www.freebsd.org/doc/en_US.ISO8859-1/books/fdp-primer/tools.html

J.2.5. Manual Installation from Source

The manual installation process of the DocBook tools is somewhat complex, so if you have pre-built packages available, use them. We describe here only a standard setup, with reasonably standard installation paths, and no "fancy" features. For details, you should study the documentation of the respective package, and read SGML introductory material.

J.2.5.1. Installing OpenJade

1. The installation of OpenJade offers a GNU-style `./configure; make; make install` build process. Details can be found in the OpenJade source distribution. In a nutshell:

   ```
   ./configure --enable-default-catalog=/usr/local/share/sgml/catalog
   make
   make install
   ```

   Be sure to remember where you put the "default catalog"; you will need it below. You can also leave it off, but then you will have to set the environment variable `SGML_CATALOG_FILES` to point to the file whenever you use jade later on. (This method is also an option if OpenJade is already installed and you want to install the rest of the toolchain locally.)

   > **Note:** Some users have reported encountering a segmentation fault using OpenJade 1.4devel to build the PDFs, with a message like:
   >
   > ```
   > openjade:./stylesheet.dsl:664:2:E: flow object not accepted by port; only display flow obj
   > make: *** [postgres-A4.tex-pdf] Segmentation fault
   > ```
   >
   > Downgrading to OpenJade 1.3 should get rid of this error.

2. Additionally, you should install the files `dsssl.dtd`, `fot.dtd`, `style-sheet.dtd`, and `catalog` from the `dsssl` directory somewhere, perhaps into `/usr/local/share/sgml/dsssl`. It's probably easiest to copy the entire directory:

   ```
   cp -R dsssl /usr/local/share/sgml
   ```

3. Finally, create the file `/usr/local/share/sgml/catalog` and add this line to it:

   ```
   CATALOG "dsssl/catalog"
   ```

   (This is a relative path reference to the file installed in step 2. Be sure to adjust it if you chose your installation layout differently.)

J.2.5.2. Installing the DocBook DTD Kit

1. Obtain the DocBook V4.2 distribution[13].
2. Create the directory `/usr/local/share/sgml/docbook-4.2` and change to it. (The exact location is irrelevant, but this one is reasonable within the layout we are following here.)

   ```
   $ mkdir /usr/local/share/sgml/docbook-4.2
   $ cd /usr/local/share/sgml/docbook-4.2
   ```

3. Unpack the archive:

   ```
   $ unzip -a ...../docbook-4.2.zip
   ```

   (The archive will unpack its files into the current directory.)

13. http://www.docbook.org/sgml/4.2/docbook-4.2.zip

4. Edit the file `/usr/local/share/sgml/catalog` (or whatever you told jade during installation) and put a line like this into it:

   ```
   CATALOG "docbook-4.2/docbook.cat"
   ```

5. Download the ISO 8879 character entities archive[14], unpack it, and put the files in the same directory you put the DocBook files in:

   ```
   $ cd /usr/local/share/sgml/docbook-4.2
   $ unzip ...../ISOEnts.zip
   ```

6. Run the following command in the directory with the DocBook and ISO files:

   ```
   perl -pi -e 's/iso-(.*).gml/ISO\1/g' docbook.cat
   ```

   (This fixes a mixup between the names used in the DocBook catalog file and the actual names of the ISO character entity files.)

J.2.5.3. Installing the DocBook DSSSL Style Sheets

To install the style sheets, unzip and untar the distribution and move it to a suitable place, for example `/usr/local/share/sgml`. (The archive will automatically create a subdirectory.)

```
$ gunzip docbook-dsssl-1.xx.tar.gz
$ tar -C /usr/local/share/sgml -xf docbook-dsssl-1.xx.tar
```

The usual catalog entry in `/usr/local/share/sgml/catalog` can also be made:

```
CATALOG "docbook-dsssl-1.xx/catalog"
```

Because stylesheets change rather often, and it's sometimes beneficial to try out alternative versions, PostgreSQL doesn't use this catalog entry. See Section J.2.6 for information about how to select the stylesheets instead.

J.2.5.4. Installing JadeTeX

To install and use JadeTeX, you will need a working installation of TeX and LaTeX2e, including the supported tools and graphics packages, Babel, AMS fonts and AMS-LaTeX, the PSNFSS extension and companion kit of "the 35 fonts", the dvips program for generating PostScript, the macro packages fancyhdr, hyperref, minitoc, url and ot2enc. All of these can be found on your friendly neighborhood CTAN site[15]. The installation of the TeX base system is far beyond the scope of this introduction. Binary packages should be available for any system that can run TeX.

Before you can use JadeTeX with the PostgreSQL documentation sources, you will need to increase the size of TeX's internal data structures. Details on this can be found in the JadeTeX installation instructions.

Once that is finished you can install JadeTeX:

```
$ gunzip jadetex-xxx.tar.gz
$ tar xf jadetex-xxx.tar
$ cd jadetex
$ make install
$ mktexlsr
```

14. http://www.oasis-open.org/cover/ISOEnts.zip
15. http://www.ctan.org

The last two need to be done as root.

J.2.6. Detection by `configure`

Before you can build the documentation you need to run the `configure` script as you would when building the PostgreSQL programs themselves. Check the output near the end of the run, it should look something like this:

```
checking for onsgmls... onsgmls
checking for openjade... openjade
checking for DocBook V4.2... yes
checking for DocBook stylesheets... /usr/share/sgml/docbook/stylesheet/dsssl/modular
checking for collateindex.pl... /usr/bin/collateindex.pl
checking for xsltproc... xsltproc
checking for osx... osx
```

If neither `onsgmls` nor `nsgmls` were found then some of the following tests will be skipped. `nsgmls` is part of the Jade package. You can pass the environment variables `JADE` and `NSGMLS` to configure to point to the programs if they are not found automatically. If "DocBook V4.2" was not found then you did not install the DocBook DTD kit in a place where Jade can find it, or you have not set up the catalog files correctly. See the installation hints above. The DocBook stylesheets are looked for in a number of relatively standard places, but if you have them some other place then you should set the environment variable `DOCBOOKSTYLE` to the location and rerun `configure` afterwards.

J.3. Building The Documentation

Once you have everything set up, change to the directory `doc/src/sgml` and run one of the commands described in the following subsections to build the documentation. (Remember to use GNU make.)

J.3.1. HTML

To build the HTML version of the documentation:

```
doc/src/sgml$ make html
```

This is also the default target. The output appears in the subdirectory `html`.

To create a proper index, the build might process several identical stages. If you do not care about the index, and just want to proof-read the output, use `draft`:

```
doc/src/sgml$ make draft
```

To build the documentation as a single HTML page, use:

```
doc/src/sgml$ make postgres.html
```

J.3.2. Manpages

We use the DocBook XSL stylesheets to convert DocBook `refentry` pages to *roff output suitable for man pages. The man pages are also distributed as a tar archive, similar to the HTML version. To create the man pages, use the commands:

```
cd doc/src/sgml
make man
```

J.3.3. Print Output via JadeTeX

If you want to use JadeTex to produce a printable rendition of the documentation, you can use one of the following commands:

- To generate PostScript via DVI in A4 format:

  ```
  doc/src/sgml$ make postgres-A4.ps
  ```

  In U.S. letter format:

  ```
  doc/src/sgml$ make postgres-US.ps
  ```

- To make a PDF:

  ```
  doc/src/sgml$ make postgres-A4.pdf
  ```

  or:

  ```
  doc/src/sgml$ make postgres-US.pdf
  ```

  (Of course you can also make a PDF version from the PostScript, but if you generate PDF directly, it will have hyperlinks and other enhanced features.)

When using JadeTeX to build the PostgreSQL documentation, you will probably need to increase some of TeX's internal parameters. These can be set in the file `texmf.cnf`. The following settings worked at the time of this writing:

```
hash_extra.jadetex  = 200000
hash_extra.pdfjadetex  = 200000
pool_size.jadetex = 2000000
pool_size.pdfjadetex = 2000000
string_vacancies.jadetex = 150000
string_vacancies.pdfjadetex = 150000
max_strings.jadetex = 300000
max_strings.pdfjadetex = 300000
save_size.jadetex = 15000
save_size.pdfjadetex = 15000
```

J.3.4. Overflow Text

Occasionally text is too wide for the printed margins, and in extreme cases, too wide for the printed page, e.g. non-wrapped text, wide tables. Overly wide text generates "Overfull hbox" messages in the TeX log output file, e.g. `postgres-US.log` or `postgres-A4.log`. There are 72 points in an inch

so anything reported as over 72 points too wide will probably not fit on the printed page (assuming one inch margins). To find the SGML text causing the overflow, find the first page number mentioned above the overflow message, e.g. `[50 ###]` (page 50), and look at the page after that (e.g. page 51) in the PDF file to see the overflow text and adjust the SGML accordingly.

J.3.5. Print Output via RTF

You can also create a printable version of the PostgreSQL documentation by converting it to RTF and applying minor formatting corrections using an office suite. Depending on the capabilities of the particular office suite, you can then convert the documentation to PostScript of PDF. The procedure below illustrates this process using Applixware.

> **Note:** It appears that current versions of the PostgreSQL documentation trigger some bug in or exceed the size limit of OpenJade. If the build process of the RTF version hangs for a long time and the output file still has size 0, then you might have hit that problem. (But keep in mind that a normal build takes 5 to 10 minutes, so don't abort too soon.)

Applixware RTF Cleanup

OpenJade omits specifying a default style for body text. In the past, this undiagnosed problem led to a long process of table of contents generation. However, with great help from the Applixware folks the symptom was diagnosed and a workaround is available.

1. Generate the RTF version by typing:

   ```
   doc/src/sgml$ make postgres.rtf
   ```

2. Repair the RTF file to correctly specify all styles, in particular the default style. If the document contains `refentry` sections, one must also replace formatting hints which tie a preceding paragraph to the current paragraph, and instead tie the current paragraph to the following one. A utility, `fixrtf`, is available in `doc/src/sgml` to accomplish these repairs:

   ```
   doc/src/sgml$ ./fixrtf --refentry postgres.rtf
   ```

   The script adds `{\s0 Normal;}` as the zeroth style in the document. According to Applixware, the RTF standard would prohibit adding an implicit zeroth style, though Microsoft Word happens to handle this case. For repairing `refentry` sections, the script replaces `\keepn` tags with `\keep`.

3. Open a new document in Applixware Words and then import the RTF file.

4. Generate a new table of contents (ToC) using Applixware.

   a. Select the existing ToC lines, from the beginning of the first character on the first line to the last character of the last line.

   b. Build a new ToC using Tools⟶Book Building⟶Create Table of Contents. Select the first three levels of headers for inclusion in the ToC. This will replace the existing lines imported in the RTF with a native Applixware ToC.

   c. Adjust the ToC formatting by using Format⟶Style, selecting each of the three ToC styles, and adjusting the indents for `First` and `Left`. Use the following values:

Style	First Indent (inches)	Left Indent (inches)
TOC-Heading 1	0.4	0.4

Style	First Indent (inches)	Left Indent (inches)
TOC-Heading 2	0.8	0.8
TOC-Heading 3	1.2	1.2

5. Work through the document to:

   - Adjust page breaks.
   - Adjust table column widths.

6. Replace the right-justified page numbers in the Examples and Figures portions of the ToC with correct values. This only takes a few minutes.
7. Delete the index section from the document if it is empty.
8. Regenerate and adjust the table of contents.

   a. Select the ToC field.
   b. Select Tools⟶Book Building⟶Create Table of Contents.
   c. Unbind the ToC by selecting Tools⟶Field Editing⟶Unprotect.
   d. Delete the first line in the ToC, which is an entry for the ToC itself.

9. Save the document as native Applixware Words format to allow easier last minute editing later.
10. "Print" the document to a file in PostScript format.

J.3.6. Plain Text Files

The installation instructions are also distributed as plain text, in case they are needed in a situation where better reading tools are not available. The `INSTALL` file corresponds to Chapter 15, with some minor changes to account for the different context. To recreate the file, change to the directory `doc/src/sgml` and enter **`make INSTALL`**.

In the past, the release notes and regression testing instructions were also distributed as plain text, but this practice has been discontinued.

J.3.7. Syntax Check

Building the documentation can take very long. But there is a method to just check the correct syntax of the documentation files, which only takes a few seconds:

```
doc/src/sgml$ make check
```

J.4. Documentation Authoring

SGML and DocBook do not suffer from an oversupply of open-source authoring tools. The most common tool set is the Emacs/XEmacs editor with appropriate editing mode. On some systems these tools are provided in a typical full installation.

J.4.1. Emacs/PSGML

PSGML is the most common and most powerful mode for editing SGML documents. When properly configured, it will allow you to use Emacs to insert tags and check markup consistency. You could use it for HTML as well. Check the PSGML web site[16] for downloads, installation instructions, and detailed documentation.

There is one important thing to note with PSGML: its author assumed that your main SGML DTD directory would be `/usr/local/lib/sgml`. If, as in the examples in this chapter, you use `/usr/local/share/sgml`, you have to compensate for this, either by setting `SGML_CATALOG_FILES` environment variable, or you can customize your PSGML installation (its manual tells you how).

Put the following in your `~/.emacs` environment file (adjusting the path names to be appropriate for your system):

```
; ********** for SGML mode (psgml)

(setq sgml-omittag t)
(setq sgml-shorttag t)
(setq sgml-minimize-attributes nil)
(setq sgml-always-quote-attributes t)
(setq sgml-indent-step 1)
(setq sgml-indent-data t)
(setq sgml-parent-document nil)
(setq sgml-exposed-tags nil)
(setq sgml-catalog-files '("/usr/local/share/sgml/catalog"))

(autoload 'sgml-mode "psgml" "Major mode to edit SGML files." t )
```

and in the same file add an entry for SGML into the (existing) definition for `auto-mode-alist`:

```
(setq
  auto-mode-alist
  '(("\\.sgml$" . sgml-mode)
   ))
```

You might find that when using PSGML, a comfortable way of working with these separate files of book parts is to insert a proper `DOCTYPE` declaration while you're editing them. If you are working on this source, for instance, it is an appendix chapter, so you would specify the document as an "appendix" instance of a DocBook document by making the first line look like this:

```
<!DOCTYPE appendix PUBLIC "-//OASIS//DTD DocBook V4.2//EN">
```

This means that anything and everything that reads SGML will get it right, and I can verify the document with `nsgmls -s docguide.sgml`. (But you need to take out that line before building the entire documentation set.)

16. http://www.lysator.liu.se/projects/about_psgml.html

J.4.2. Other Emacs Modes

GNU Emacs ships with a different SGML mode, which is not quite as powerful as PSGML, but it's less confusing and lighter weight. Also, it offers syntax highlighting (font lock), which can be very helpful. `src/tools/editors/emacs.samples` contains sample settings for this mode.

Norm Walsh offers a major mode[17] specifically for DocBook which also has font-lock and a number of features to reduce typing.

J.5. Style Guide

J.5.1. Reference Pages

Reference pages should follow a standard layout. This allows users to find the desired information more quickly, and it also encourages writers to document all relevant aspects of a command. Consistency is not only desired among PostgreSQL reference pages, but also with reference pages provided by the operating system and other packages. Hence the following guidelines have been developed. They are for the most part consistent with similar guidelines established by various operating systems.

Reference pages that describe executable commands should contain the following sections, in this order. Sections that do not apply can be omitted. Additional top-level sections should only be used in special circumstances; often that information belongs in the "Usage" section.

Name

This section is generated automatically. It contains the command name and a half-sentence summary of its functionality.

Synopsis

This section contains the syntax diagram of the command. The synopsis should normally not list each command-line option; that is done below. Instead, list the major components of the command line, such as where input and output files go.

Description

Several paragraphs explaining what the command does.

Options

A list describing each command-line option. If there are a lot of options, subsections can be used.

Exit Status

If the program uses 0 for success and non-zero for failure, then you do not need to document it. If there is a meaning behind the different non-zero exit codes, list them here.

Usage

Describe any sublanguage or run-time interface of the program. If the program is not interactive, this section can usually be omitted. Otherwise, this section is a catch-all for describing run-time features. Use subsections if appropriate.

17. http://nwalsh.com/emacs/docbookide/index.html

Environment

List all environment variables that the program might use. Try to be complete; even seemingly trivial variables like `SHELL` might be of interest to the user.

Files

List any files that the program might access implicitly. That is, do not list input and output files that were specified on the command line, but list configuration files, etc.

Diagnostics

Explain any unusual output that the program might create. Refrain from listing every possible error message. This is a lot of work and has little use in practice. But if, say, the error messages have a standard format that the user can parse, this would be the place to explain it.

Notes

Anything that doesn't fit elsewhere, but in particular bugs, implementation flaws, security considerations, compatibility issues.

Examples

Examples

History

If there were some major milestones in the history of the program, they might be listed here. Usually, this section can be omitted.

Author

Author (only used in the contrib section)

See Also

Cross-references, listed in the following order: other PostgreSQL command reference pages, PostgreSQL SQL command reference pages, citation of PostgreSQL manuals, other reference pages (e.g., operating system, other packages), other documentation. Items in the same group are listed alphabetically.

Reference pages describing SQL commands should contain the following sections: Name, Synopsis, Description, Parameters, Outputs, Notes, Examples, Compatibility, History, See Also. The Parameters section is like the Options section, but there is more freedom about which clauses of the command can be listed. The Outputs section is only needed if the command returns something other than a default command-completion tag. The Compatibility section should explain to what extent this command conforms to the SQL standard(s), or to which other database system it is compatible. The See Also section of SQL commands should list SQL commands before cross-references to programs.

Appendix K. Acronyms

This is a list of acronyms commonly used in the PostgreSQL documentation and in discussions about PostgreSQL.

ANSI

American National Standards Institute[1]

API

Application Programming Interface[2]

ASCII

American Standard Code for Information Interchange[3]

BKI

Backend Interface

CA

Certificate Authority[4]

CIDR

Classless Inter-Domain Routing[5]

CPAN

Comprehensive Perl Archive Network[6]

CRL

Certificate Revocation List[7]

CSV

Comma Separated Values[8]

CTE

Common Table Expression

CVE

Common Vulnerabilities and Exposures[9]

DBA

Database Administrator[10]

1. http://en.wikipedia.org/wiki/American_National_Standards_Institute
2. http://en.wikipedia.org/wiki/API
3. http://en.wikipedia.org/wiki/Ascii
4. http://en.wikipedia.org/wiki/Certificate_authority
5. http://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing
6. http://www.cpan.org/
7. http://en.wikipedia.org/wiki/Certificate_revocation_list
8. http://en.wikipedia.org/wiki/Comma-separated_values
9. http://cve.mitre.org/
10. http://en.wikipedia.org/wiki/Database_administrator

DBI

Database Interface (Perl)[11]

DBMS

Database Management System[12]

DDL

Data Definition Language[13], SQL commands such as `CREATE TABLE`, `ALTER USER`

DML

Data Manipulation Language[14], SQL commands such as `INSERT`, `UPDATE`, `DELETE`

DST

Daylight Saving Time[15]

ECPG

Embedded C for PostgreSQL

ESQL

Embedded SQL[16]

FAQ

Frequently Asked Questions[17]

FSM

Free Space Map

GEQO

Genetic Query Optimizer

GIN

Generalized Inverted Index

GiST

Generalized Search Tree

Git

Git[18]

GMT

Greenwich Mean Time[19]

GSSAPI

Generic Security Services Application Programming Interface[20]

GUC

Grand Unified Configuration, the PostgreSQL subsystem that handles server configuration

11. http://dbi.perl.org/
12. http://en.wikipedia.org/wiki/Dbms
13. http://en.wikipedia.org/wiki/Data_Definition_Language
14. http://en.wikipedia.org/wiki/Data_Manipulation_Language
15. http://en.wikipedia.org/wiki/Daylight_saving_time
16. http://en.wikipedia.org/wiki/Embedded_SQL
17. http://en.wikipedia.org/wiki/FAQ
18. http://en.wikipedia.org/wiki/Git_(software)
19. http://en.wikipedia.org/wiki/GMT
20. http://en.wikipedia.org/wiki/Generic_Security_Services_Application_Program_Interface

HBA

: Host-Based Authentication

HOT

: Heap-Only Tuples[21]

IEC

: International Electrotechnical Commission[22]

IEEE

: Institute of Electrical and Electronics Engineers[23]

IPC

: Inter-Process Communication[24]

ISO

: International Organization for Standardization[25]

ISSN

: International Standard Serial Number[26]

JDBC

: Java Database Connectivity[27]

LDAP

: Lightweight Directory Access Protocol[28]

MSVC

: Microsoft Visual C[29]

MVCC

: Multi-Version Concurrency Control

NLS

: National Language Support[30]

ODBC

: Open Database Connectivity[31]

OID

: Object Identifier

OLAP

: Online Analytical Processing[32]

21. http://git.postgresql.org/gitweb?p=postgresql.git;a=blob;f=src/backend/access/heap/README.HOT;hb=HEAD
22. http://en.wikipedia.org/wiki/International_Electrotechnical_Commission
23. http://standards.ieee.org/
24. http://en.wikipedia.org/wiki/Inter-process_communication
25. http://www.iso.org/iso/home.htm
26. http://en.wikipedia.org/wiki/Issn
27. http://en.wikipedia.org/wiki/Java_Database_Connectivity
28. http://en.wikipedia.org/wiki/Lightweight_Directory_Access_Protocol
29. http://en.wikipedia.org/wiki/Visual_C++
30. http://en.wikipedia.org/wiki/Internationalization_and_localization
31. http://en.wikipedia.org/wiki/Open_Database_Connectivity
32. http://en.wikipedia.org/wiki/Olap

OLTP

Online Transaction Processing[33]

ORDBMS

Object-Relational Database Management System[34]

PAM

Pluggable Authentication Modules[35]

PGSQL

PostgreSQL

PGXS

PostgreSQL Extension System

PID

Process Identifier[36]

PITR

Point-In-Time Recovery (Continuous Archiving)

PL

Procedural Languages (server-side)

POSIX

Portable Operating System Interface[37]

RDBMS

Relational Database Management System[38]

RFC

Request For Comments[39]

SGML

Standard Generalized Markup Language[40]

SPI

Server Programming Interface

SP-GiST

Space-Partitioned Generalized Search Tree

SQL

Structured Query Language[41]

SRF

Set-Returning Function

33. http://en.wikipedia.org/wiki/OLTP
34. http://en.wikipedia.org/wiki/ORDBMS
35. http://en.wikipedia.org/wiki/Pluggable_Authentication_Modules
36. http://en.wikipedia.org/wiki/Process_identifier
37. http://en.wikipedia.org/wiki/POSIX
38. http://en.wikipedia.org/wiki/Relational_database_management_system
39. http://en.wikipedia.org/wiki/Request_for_Comments
40. http://en.wikipedia.org/wiki/SGML
41. http://en.wikipedia.org/wiki/SQL

SSH

Secure Shell[42]

SSL

Secure Sockets Layer[43]

SSPI

Security Support Provider Interface[44]

SYSV

Unix System V[45]

TCP/IP

Transmission Control Protocol (TCP) / Internet Protocol (IP)[46]

TID

Tuple Identifier

TOAST

The Oversized-Attribute Storage Technique

TPC

Transaction Processing Performance Council[47]

URL

Uniform Resource Locator[48]

UTC

Coordinated Universal Time[49]

UTF

Unicode Transformation Format[50]

UTF8

Eight-Bit Unicode Transformation Format[51]

UUID

Universally Unique Identifier

WAL

Write-Ahead Log

XID

Transaction Identifier

42. http://en.wikipedia.org/wiki/Secure_Shell
43. http://en.wikipedia.org/wiki/Secure_Sockets_Layer
44. http://msdn.microsoft.com/en-us/library/aa380493%28VS.85%29.aspx
45. http://en.wikipedia.org/wiki/System_V
46. http://en.wikipedia.org/wiki/Transmission_Control_Protocol
47. http://www.tpc.org/
48. http://en.wikipedia.org/wiki/URL
49. http://en.wikipedia.org/wiki/Coordinated_Universal_Time
50. http://www.unicode.org/
51. http://en.wikipedia.org/wiki/Utf8

XML

Extensible Markup Language[52]

52. http://en.wikipedia.org/wiki/XML

Bibliography

Selected references and readings for SQL and PostgreSQL.

Some white papers and technical reports from the original POSTGRES development team are available at the University of California, Berkeley, Computer Science Department web site[1].

SQL Reference Books

Judith Bowman, Sandra Emerson, and Marcy Darnovsky, *The Practical SQL Handbook: Using SQL Variants*, Fourth Edition, Addison-Wesley Professional, ISBN 0-201-70309-2, 2001.

C. J. Date and Hugh Darwen, *A Guide to the SQL Standard: A user's guide to the standard database language SQL*, Fourth Edition, Addison-Wesley, ISBN 0-201-96426-0, 1997.

C. J. Date, *An Introduction to Database Systems*, Eighth Edition, Addison-Wesley, ISBN 0-321-19784-4, 2003.

Ramez Elmasri and Shamkant Navathe, *Fundamentals of Database Systems*, Fourth Edition, Addison-Wesley, ISBN 0-321-12226-7, 2003.

Jim Melton and Alan R. Simon, *Understanding the New SQL: A complete guide*, Morgan Kaufmann, ISBN 1-55860-245-3, 1993.

Jeffrey D. Ullman, *Principles of Database and Knowledge: Base Systems*, Volume 1, Computer Science Press, 1988.

PostgreSQL-specific Documentation

Stefan Simkovics, *Enhancement of the ANSI SQL Implementation of PostgreSQL*, Department of Information Systems, Vienna University of Technology, November 29, 1998.

Discusses SQL history and syntax, and describes the addition of `INTERSECT` and `EXCEPT` constructs into PostgreSQL. Prepared as a Master's Thesis with the support of O. Univ. Prof. Dr. Georg Gottlob and Univ. Ass. Mag. Katrin Seyr at Vienna University of Technology.

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